Journal of Neurosurgery

Medical Library

MAY 1955

VOLUME XII MAY 1955 NUMBER 3

JOURNAL OF NEUROSURGERY

[*J. Neurosurg.*]

MANAGING EDITOR

LOUISE EISENHARDT, 333 Cedar Street, New Haven 11, Conn.

EDITORIAL BOARD

WINCHELL McK. CRAIG, Rochester, Minn., *Chairman*

PAUL C. BUCY, Chicago
BRONSON S. RAY, New York
FRANC D. INGRAHAM, Boston
BARNES WOODHALL, Durham

ADVISORY BOARD

A. ASENJO, Santiago de Chile
HOWARD C. NAFFZIGER, San Francisco
GILBERT HORRAX, Boston
HERBERT OLIVECRONA, Stockholm
GEOFFREY JEFFERSON, Manchester, Eng.
WILDER PENFIELD, MONTREAL
KENNETH G. McKENZIE, Toronto
D. PETIT-DUTAILLIS, Paris
W. JASON MIXTER, Boston
ERNEST SACHS, New Haven
R. GLEN SPURLING, Louisville

PUBLISHED BI-MONTHLY

FOR THE HARVEY CUSHING SOCIETY BY

CHARLES C THOMAS, Publisher

301-327 EAST LAWRENCE AVENUE, SPRINGFIELD, ILLINOIS, U.S.A.

Copyright, 1955, by Charles C Thomas, Publisher. Subscription rates: $11.00 a year in the United States, Pan-American Union, and Spain; $11.50 a year in Canada; $12.00 a year in other countries; single copies, $2.00 postpaid. Single copies of Volume VIII, Number 1, January 1951 issue: Symposium on Intracranial Vascular Abnormalities: $3.00 postpaid, if available.

Distributed in the British Commonwealth of Nations by Blackwell Scientific Publications, Ltd., 24–25 Broad Street, Oxford, England. Copyrighted in the British Commonwealth by Blackwell Scientific Publications, Oxford. No part may be duplicated or reproduced without permission of publishers. Subscription price £4.7.6.

Entered as second-class matter March 12, 1944 at the post office at Springfield, Illinois, under the act of March 3, 1879. Additional Entry at the post office at Menasha, Wisconsin.

PRINTED IN U.S.A.

for positive

identification

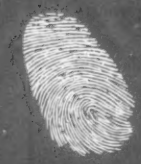
Gudebrod

COLOR CODED

TRADE MARK PAT. APPLIED FOR

SUTURES

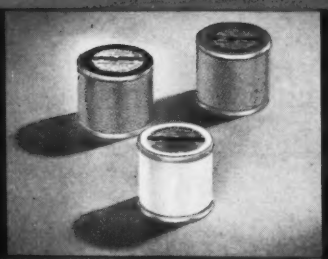
4-0 PINK 3-0 BLUE 00 WHITE



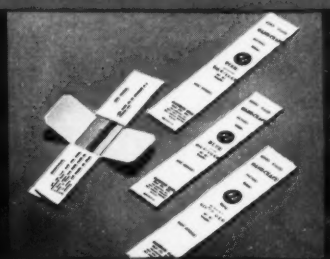
Correct size suture is immediately selected when the ORN supplies Gudebrod COLOR CODED—no hesitation, never a question.

An exclusive GUDEBROD feature SURE AS A FINGERPRINT

Available in CHAMPION serum-proof silk or HAND-CRAFT cotton



SPOOLS



GUDE-PACK

BRI-PAK®

NEUROCHEMISTRY

The Chemical Dynamics of Brain and Nerve

Edited by

K. A. C. ELLIOTT, M.Sc., Ph.D., Sc.D.
Neurochemist and Donner Fellow
Montreal Neurological Institute
Associate Professor of Experimental Neurology and Biochemistry
McGill University, Montreal, Quebec

IRVINE H. PAGE, M.D.
Director of Research
Cleveland Clinic, Cleveland, Ohio

and

J. H. QUASTEL, D.Sc., Ph.D.
Director, Research Institute
The Montreal General Hospital
Professor of Biochemistry
McGill University, Montreal, Quebec

THIRTY-TWO ARTICLES

Written by experienced investigators in their respective fields

Opposing views are frankly presented, so that a true perspective of the PRESENT SITUATION IN THE NEUROCHEMICAL FIELD is obtained.

THE ULTIMATE OBJECTIVE OF NEUROCHEMISTRY, in partnership with Neurophysiology and Neuropathology, is the understanding of the phenomena underlying the behavior of nerve, brain and mind, and the maladies to which they are subject. THE FURTHERANCE OF THIS UNDERSTANDING IS THE AIM OF THIS WORK.

This book attempts to give, for the first time, an account of our present knowledge of the chemistry of the nervous system and its bearing on neurological phenomena. It is written for a wide circle of investigators and students, for the biochemist and the physiologist, for the neurologist, neuropathologist and the neurosurgeon, for the clinician, the pharmacologist; indeed, for all interested in the workings in the nervous system, whether it be in man or in the insect.

This book, intended as a monument to Thudicum, the first to undertake systematic study of the chemistry of the brain, is, in fact, a foundation for all future work on the chemical dynamics of brain and nerve.

In it is collected all relevant information, as up-to-date as possible in a book that has required some years for its preparation, on a variety of aspects of neurochemistry, neurophysiology and neurology.

Here are described the chemical constituents of brain and nerve, the factors influencing respiration and other metabolic phenomena of the nervous system, the effects of narcotics and convulsants, venoms and nerve poisons.

The biochemistry of the brain during its early development, the composition and behaviour of intracranial fluids, the significance of acetylcholine in nerve physiology, nutritional, genetic, and behavioural disorders in the nervous system, and neuromuscular diseases—all these and a variety of other topics are discussed in full.

916 pages *101 illustrations*

Sent on approval, $19.50, postpaid

CHARLES C THOMAS • PUBLISHER • SPRINGFIELD • ILLINOIS

"...a potent antihemorrhagic factor"*

in use in more than 2500 hospitals

Adrenosem controls capillary bleeding and oozing by acting directly on the walls of the blood vessels. It decreases permeability.

This unique hemostat does not alter blood components, nor does it affect cardiac rate or volume. Useful both prophylactically and therapeutically, it is notable for a high index of therapeutic safety. Supplied in ampuls, tablets and as a syrup.

*Sherber, P.A.: The control of bleeding, Am. J. Surg. 86:331 (Sept.) 1953.

Indicated in postoperative bleeding associated with:
Tonsillectomy, adenoidectomy and nasopharynx surgery
Prostatic and bladder surgery
Uterine bleeding
Postpartum hemorrhage
Dental surgery
Chest surgery and chronic pulmonary bleeding
Also: Idiopathic purpura
Retinal hemorrhage
Familial telangiectasia
Epistaxis
Hematuria

The unique systemic hemostat

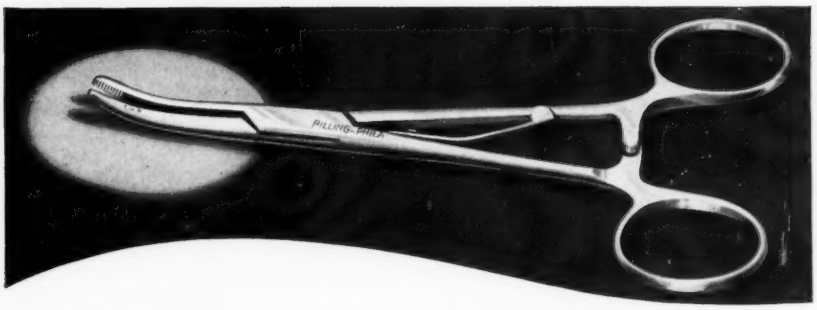
Send for detailed literature

adrenosem®

SALICYLATE

(BRAND OF CARBAZOCHROME SALICYLATE)

THE S. E. MASSENGILL COMPANY, Bristol, Tennessee



Uses "U" clips

or "V" clips

CLIP APPLYING FORCEPS *as modified by John H. Drew, M.D., Boston*

Clips will not stick or jam

In actual operating room use, Drew Forceps

1. entirely eliminate the problem of clips jamming or catching in the jaws of the forceps
2. hold clips more securely—they are not dislodged during transfer from nurse to surgeon
3. are easier to use—with Drew forceps the nurse picks clips off the McKenzie magazine with much less effort or trouble than with the standard forceps.

Write for complete listing of clip applying forceps with Drew jaws.

Ref.: Drew, J.H.: J. Neurosurg. 10:439 (July) 1953.

THE AUTHENTIC INSTRUMENT IS AVAILABLE ONLY FROM PILLING . . . *ORDER DIRECT:*

GEORGE P. **Pilling** & SON CO.

3451 WALNUT STREET . . . . . PHILADELPHIA

Automatically controlled

SERIAL

Angiography

Model 110 Universal Automatic Seriograph

Here is automatically controlled serial angiography with highest quality, standard size pictures and standard developing procedures!

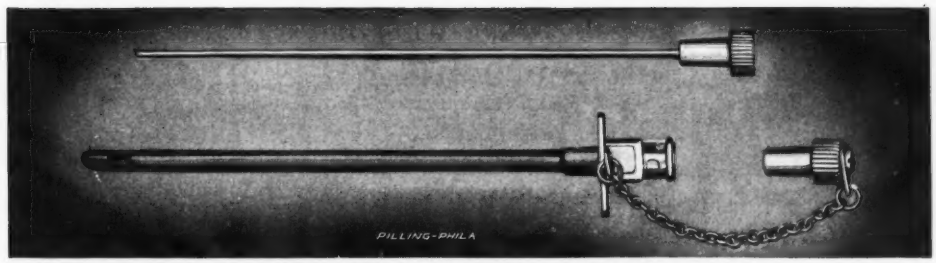
Full control by Radiologist permits test pictures and delays during picture cycle. The 12 individual cassettes, each with its own set of screens, give you 11" x 14" (or smaller) standard pictures for adult angiographic studies.

Seriograph operation is equally efficient in the horizontal or vertical position. Automatic time selector gives ½ to 2 second infinitely variable interval.

For details of these and many other outstanding features of the new Model 110 Universal Automatic Seriograph write to:

The **Automatic Seriograph Corp.**

4910 Calvert Road • College Park • Maryland



RUBBER VENTRICULAR CANNULA & INDWELLING CATHETER

Designed by Michael Scott, M.D , Philadelphia

For Ventricular Tapping, and Injection or Removal of Air or Fluid

- No danger of damage to brain by movement of scalp
- Original insertion puts catheter in place—less trauma than metal cannula plus catheter
- Cannula-catheter can be left *in situ* for days without unusual irritation
- Especially valuable during a craniotomy—ventricle tapped, cannula left in place, brain retracted, without danger of catheter damage
- Any system may be Luer-locked to the cannula for continuous injection, pressure estimation or drainage

35-1611 Scott Cannula-Catheter, 8 Fr. . . 6 cm.
35-1612 . . . . . 8 cm.
35-1613 . . . . . 10 cm.
35-1614 set of three: one each 6, 8 and 10 cm.

Ref: Scott, M.: J. Neurosurg. 10:438 (July) 1953.

THE AUTHENTIC INSTRUMENT IS AVAILABLE ONLY FROM PILLING . . . *ORDER DIRECT:*

GEORGE P. **Pilling** & SON CO.

3451 WALNUT STREET . . . . . PHILADELPHIA

BUCY-FRAZIER *Coagulating* SUCTION CANNULA

An efficient instrument, particularly for neurosurgical procedures, this is a modified Frazier suction cannula with a Luer-Lok terminal connection and a connecting cord fitted with a Bovie plug. The cannula is completely insulated with a special neoprene coating for combined coagulation and suction.

THREE STANDARD SIZES:

NL-1750
Small, 10 Fr. . . . . Each, $10.50

NL-1751
Medium, 12 Fr. . . . . Each, $10.50

NL-1752
Large, 14 Fr. . . . . Each, $11.50

Instrument Makers To The Profession Since 1895

V. Mueller & Co.

330 SOUTH HONORE STREET, CHICAGO 12, ILLINOIS
BRANCHES NOW IN ROCHESTER, MINN.—DALLAS AND HOUSTON, TEXAS

Cytoarchitectonic Atlas of the Rhombencephalon of the Rabbit

by Dr. H. MEESSEN, Düsseldorf and Dr. J. OLSZEWSKI, Montreal

52 p., 69 fig., 15 plates, 1949. Sw. frs. 52.00

Through this new elaboration of the cyto-architectonic of the rhombencephalon a new and rich reference system has been established, furnishing an anatomic basis for every experimental work that deals with this part of the brain. The results are shown in 15 pictures of the original anatomical preparations enlarged 40 times, and completed with part pictures enlarged 200 times and with pictures of cells enlarged 1000 times. A short introduction, the accompanying text, and a survey of the parts studied allow the plates to be of practical use even to those who are not specialists. The anatomist, the student of comparative anatomy, the neuropathologist and neurophysiologist will welcome the illustrative material of this book.

Excerpta Medica (Sect. 1, Vol. 4, Fasc. 1): "The work is beautifully illustrated, paper and printing are of high quality. The atlas must be considered as very important for everyone interested in comparative neuro-anatomy and cytology of the brain."

BASEL 11 (Switzerland) S. KARGER NEW YORK

For U.S.A.: Albert J. Phiebig, P.O. Box 352, White Plains, N.Y.

«Chronic Otitis»

A Critical Analysis

By MARCUS DIAMANT, Halmstad

190 pages, 35 figures, 1 plate; 1952. Sw. frs. 23.00

(Suppl. ad Vol. 14 «Practica Oto-Rhino-Laryngologica»)

This book is going to be a very definitive contribution to our knowledge of the subject of the chronic ear. The numerous problems involved have been divided into separate parts under detailed headings. This should allow the reader to make his own choice, and thus give him the opportunity of reading only those parts which are of special interest to him. The problem of "Chronic Otitis" as well as *Wittmaack's* pneumatization theory had to be dealt with in their entirety.

The Function of the

Vestibular Organ

By A. A. J. VAN EGMOND, J. J. GROEN and L. B. W. JONGKEES

University of Utrecht

109 pages, 17 figures; 1952. Sw. frs. 14.00

(Suppl. ad Vol. 14 «Practica Oto-Rhino-Laryngologica»)

BASEL 11 (Switzerland) S. KARGER NEW YORK

For U.S.A.: Albert J. Phiebig, P.O. Box 352, White Plains, N.Y.

HYPEROSTOSIS CRANII

Stewart-Morel Syndrome: Metabolic Craniopathy
Morgagni's Syndrome:
Stewart-Morel-Moore Syndrome (Ritvo)
Le Syndrome de Morgagni-Morel

By

SHERWOOD MOORE, M.D.
Professor Emeritus of Radiology
Washington University School of Medicine

A ROENTGEN, CLINICAL and ANATOMICAL study based on 522 Hyperostotics, 1267 Controls, and 1478 Skeletons. Written for **Radiologists, Neuropsychiatrists, Neurosurgeons, Endocrinologists, Anatomists, Investigators** and **Paleopathologists.** The antithesis of Hyperostosis Craniì, Hypoplasia of the Diploe is described. The SOCIAL and ECONOMIC aspects of the syndrome are discussed. TREATMENT and PROGNOSIS are considered. The statistics in this work have been critically analysed and verified. Paleopathology is as fully considered as limited data permitted.

The HISTORY of the disorder is given in full with a chronologically arranged bibliography.

Emphasis is placed on the part played by the **pituitary, thyroid** and **gonads** in the syndrome and of the circulation in producing and localizing the hyperostosis.

The PATHOLOGY of the condition is described.
The theories of the ETIOLOGY, PATHOGENESIS and MORPHOGENESIS of Hyperostosis Cranii and its Syndrome are discussed.

Four types and degrees of HYPEROSTOSIS and THEIR COMBINATIONS are described.

A standard of the Roentgen dimension of the normal human skull is established both for living subjects and museum material. Roentgen and conventional craniometric measurements are checked against each other.

The Roentgen dimensions of the hyperostotic cranium in LIVING and MUSEUM material are compared with the NORMAL.

260 pages **129 illustrations** **Sent on approval, $10.50 postpaid**

CHARLES C THOMAS · PUBLISHER · SPRINGFIELD · ILLINOIS

MINIATURE PROBE COUNTER TUBE FOR NEUROSURGERY

(Robinson-Selverstone Type)

LELAB Probe Counter Tubes are made especially for neurological surgery and other medical uses requiring a miniature probe. They provide a satisfactory way of measuring radioactivity *in vivo* and for probing small areas with relatively strong field intensities.

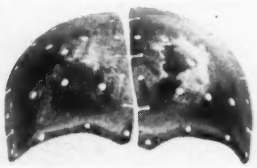
The stainless steel probing needle has an outside diameter of .080 inches. The sensitive volume starts about 5 mm. from the tip of the needle and extends to about 17 mm. from the tip. As an aid in detecting the depth of penetration, the probe is graduated in 1 cm. divisions, starting at the far end of the sensitive volume and extending for a distance of 10 cm., the total needle length.

Write Dept. P for further information

H. W. LEIGHTON LABORATORIES
26 Herman St. Glen Ridge, N.J.

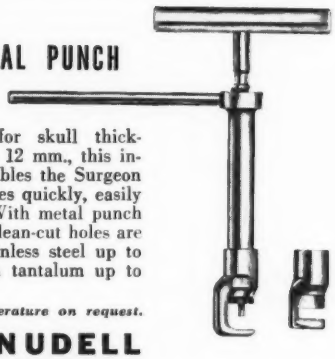
NOW AVAILABLE . . .

NUDELL'S PRE-FORMED TEMPLATES FOR THE FRONTAL and SUPRAORBITAL RIDGE



This addition to Nudell's Universal Templates saves surgeons time in fitting a most difficult area. Available in stainless steel or tantalum, right or left side.

SKULL AND METAL PUNCH



Adjustable for skull thicknesses up to 12 mm., this instrument enables the Surgeon to punch holes quickly, easily and safely. With metal punch attachment clean-cut holes are made in stainless steel up to .0015 and in tantalum up to .0020.

Prices and literature on request.

UZA NUDELL
Technician to Neuro-Surgeons
125 W. 45TH STREET NEW YORK 36, N.Y.

PREFRONTAL LEUCOTOMY AND RELATED OPERATIONS

Anatomical Aspects of Success and Failure

By
ALFRED MEYER, M.D., *Professor of Neuropathology*
ELIZABETH BECK, *Research Assistant*
Institute of Psychiatry
University of London

This is an analysis of the clinical and anatomical data of 102 brains upon which prefrontal leucotomy and related operations have been performed.

Because this is by far the largest collection of brains of this kind, the results of the study form a valuable supplement to clinical surveys.

Some of the conclusions reached by the authors strengthen the recent trends of avoidance of the dorsal and lateral convexity of the brain; they also convey a warning against a too dogmatic localization of function within the frontal lobe.

64 pages *31 illustrations*

Sent on approval, $2.25, postpaid

CHARLES C THOMAS • PUBLISHER • SPRINGFIELD • ILLINOIS

THE CLINICAL PHYSIOLOGY OF THE LUNGS

By

CECIL K. DRINKER, M.D., D.Sc.

Formerly, Professor of Physiology
Harvard University, School of Public Health
Boston, Massachusetts

This book considers the BASIC STRUCTURAL COMPONENTS of the lungs for accomplishing the *constant adaptations which occur during breathing:*

ARTERIES
VEINS AND CAPILLARIES
BRONCHIOLES
NERVES
LYMPHATICS

The writing is informal and suggestive and is designed to give impetus to thinking.

96 pages **22 illustrations**

Sent on approval, $5.50, postpaid

CHARLES C THOMAS · PUBLISHER
SPRINGFIELD · ILLINOIS

MEASURE
Sensory Changes

The Bio-Thesiometer® enables you to make *improved* sensory tests because it *MEASURES* sensory changes. The results are expressed in numbers as they are in measuring blood pressure, temperature or other quantitative tests.

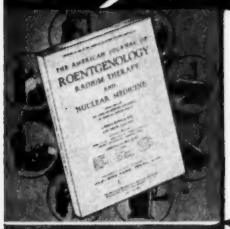
In addition to giving you quantitative and diagnostic data in your first test, owners emphasize "it is also valuable in following the progress of the disease, whether there is improvement or lack of improvement."

The Bio-Thesiometer® test replaces qualitative and non-standardized tests of sensation. The results are expressed in relative or absolute units which have exactly the same meaning to all those making such tests.

The Bio-Thesiometer is a new tool for the diagnosis of many conditions in which the nervous system or vascular system is involved. May we send you complete information? Write to

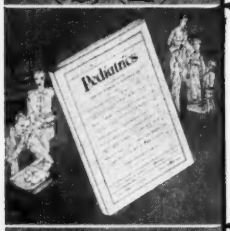
BIO-MEDICAL INSTRUMENT COMPANY
24 Munn Road
NEWBURY, OHIO

Six Keys to Success!



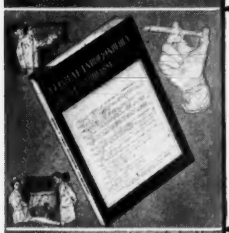
The American Journal of Roentgenology Radium Therapy and Nuclear Medicine

Official Organ—The American Roentgen Ray Society and The American Radium Society. Edited by **Lawrence Reynolds.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $15.00; Canada, $16.00; other foreign countries, $17.00. Monthly.



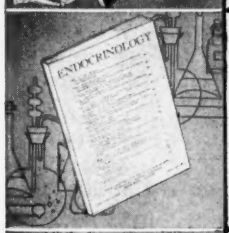
Pediatrics

Official Journal—American Academy of Pediatrics. Edited by **Charles D. May.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $12.00; Canada, $13.00; other foreign countries, $14.00. Monthly.



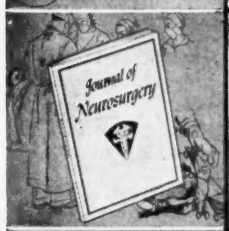
The Journal of Clinical Endocrinology and Metabolism

Official Journal—The Endocrine Society. Edited by **Phebe K. Thompson.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $13.00; Canada, $13.50; other foreign countries, $14.00. Monthly.



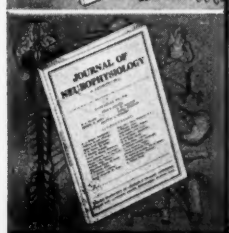
Endocrinology

Official Journal—The Endocrine Society. Edited by **Roy O. Greep.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $13.00; Canada, $13.50; other foreign countries, $14.00. Monthly.



Journal of Neurosurgery

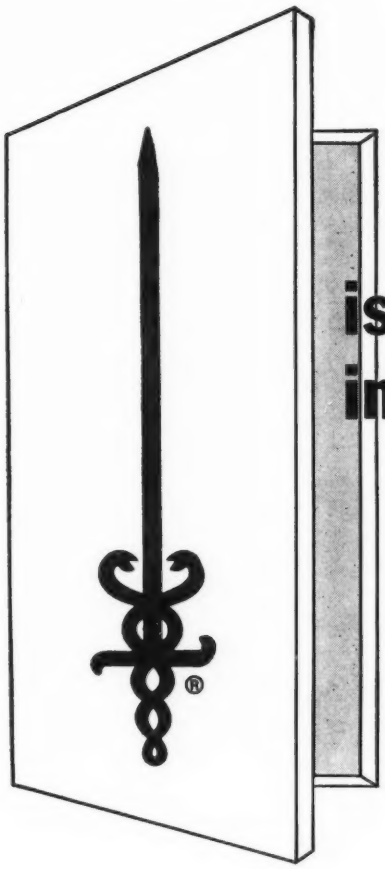
Official Journal—The Harvey Cushing Society. Edited by **Louise Eisenhardt.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $11.00; Canada, $11.50; other foreign countries. $12.00 Bi-monthly.



Journal of Neurophysiology

Editorial Board: **John F. Fulton, H. A. Blair, Hebbel E. Hoff, P. D. MacLean, H. W. Magoun, Donal Sheehan, Clinton N. Woolsey.** Price a year: United States, U. S. Possessions, Pan-American Union and Spain, $9.50; Canada, $10.00; other foreign countries, $10.50. Bi-monthly.

CHARLES C THOMAS • PUBLISHER • SPRINGFIELD • ILLINOIS



is there a doctor in the house?

There certainly is in our house.

Where there is activity against cancer, there is the physician. It is no secret to any of you that the doctor contributes long hours to the needy cancer patient in clinics, in hospitals, in homes. It is your office of which we boast when we say "every doctor's office a cancer detection center."

Less well known is the fact that hundreds of your colleagues, as directors of the American Cancer Society nationally, in Divisions, and with Units, bring the best medical thought to our attack on cancer by education, by research, and by service to patients. The entire professional education program is planned for doctors by doctors.

The occasion for this brief salute is April, the Cancer Control Month. This year, 1955, marks the tenth anniversary of the reorganization of the American Cancer Society and the launching of the post-war attack on cancer. Much has been achieved—far more remains to be done.

We are grateful for your help in the past—and we rely on your continued support. We count heavily on the doctor in our house.

American Cancer Society

Cranioplastic

RESINOUS MATERIAL FOR REPAIRING CRANIAL DEFECTS

A method of rapidly repairing cranial defects using a resin material containing Methyl-methacrylate which is molded into the cranial defect at the time of the original operation. This highly refined plastic has been used since 1947 and to date it has not been necessary to remove a single plate.

N-196 CRANIOPLASTIC KIT

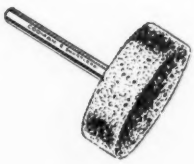
Contains 3 packets of powder (sterile), 3 ampules of liquid (sterile) and 3 matrix bags which is sufficient material for the repair of three ordinary cranial defects.

N-197 SPENCE CRANIOPLASTIC ROLLER

A stainless steel roller which is of great help in rolling the plastic mass to the desired thickness before fitting to the cranial defect.

N-198 CARBORUNDUM WHEEL

Used with bone saw or drill to bevel edges and smooth rough spots. Can be autoclaved.



Ref.: Spence, William T.: Form Fitting Plastic Cranioplasty. Journal of Neurosurgery. May, 1954.

ESTABLISHED 1838

Codman & Shurtleff, Inc.

MAKERS OF SURGEONS' INSTRUMENTS

104 BROOKLINE AVENUE BOSTON 15, MASSACHUSETTS

ANGIOGRAPHY IN THE MANAGEMENT OF INTRA- AND SUPRA-SELLAR TUMOURS*

R. A. MONEY, F.R.C.S., AND G. K. VANDERFIELD, M.B., B.S.
Department of Neurosurgery, Royal Prince Alfred Hospital, Sydney, Australia

(Received for publication December 20, 1954)

THE development of cerebral angiography, and its ready availability in any modern neurosurgical centre, has led to its wide application to clinical problems.

Since the beginning of 1952, carotid angiography has been used extensively in the pre-operative evaluation of suspected intra- and supra-sellar tumours (including those tumours arising from the olfactory groove and in the third ventricle), and sometimes postoperatively as well. This procedure has been found very helpful in a recent series of 21 cases, and it is considered to be worthy of presentation.

PROCEDURE OF ANGIOGRAPHY

When an assessment of the neurological status has suggested, or established, the presence of a tumour in the region of the sella turcica, bilateral carotid angiography is carried out to secure the fullest possible information about the situation and size of the lesion and to enable the safest and easiest surgical approach to be made, if operation is necessary.

In order to reduce the risk of arterial spasm, 130 mg. of papaverine are given intramuscularly, just prior to the procedure, which is carried out either under local anaesthesia, or under a basal dose of avertin if the patient is not fully co-operative. Each common carotid artery is cannulated percutaneously in turn, and anteroposterior and lateral series of angiograms are taken, on each side, after injections of 10 cc. of 35 per cent diodrast.

At this stage, sufficient information is usually available to enable a definite diagnosis to be made and a suitable operative approach to be planned. However, should satisfactory filling of the anterior cerebral arteries not be seen, then pneumoencephalography is carried out, unless there is evidence of internal hydrocephalus (as indicated by "stretching" of the anterior cerebral arteries or by a raised intracranial pressure) when pneumoencephalography would be contra-indicated and ventriculography would have to be done, before proceeding to surgery. In either instance, special attention would be paid to "filling" skiagrams, and to brow-up anteroposterior and lateral skiagrams, showing the anterior portions of the lateral ventricles, the third ventricle and the basal cisternae, especially chiasmatis and interpeduncularis.

* Read at the Sixth Congress of the Pan-Pacific Surgical Association held in Honolulu, October, 1954.

DIAGNOSTIC FEATURES OF ANGIOGRAMS

(a) *Displacement of Major Blood Vessels.* In cases of tumours arising from within the sella turcica, the intracranial portions of the internal carotid arteries appear to be elongated and the "siphon" is opened-out. The terminal

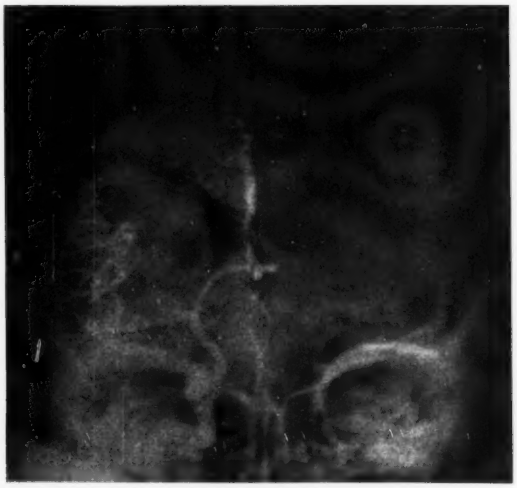


FIG. 1. *Case 1.* Anteroposterior angiogram showing upward displacement of anterior cerebral artery and the obtuse angle it makes with the terminal part of the internal carotid artery.

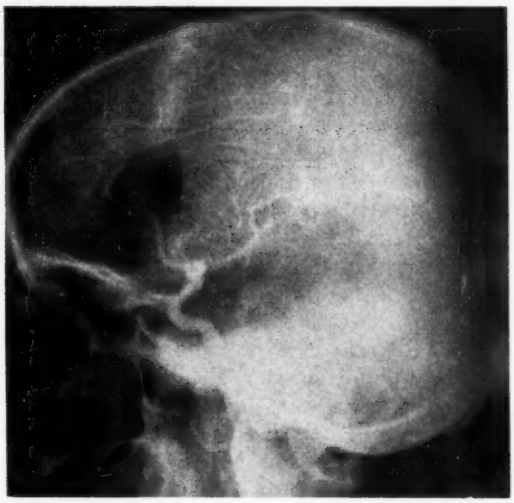


FIG. 2. *Case 9.* Showing marked "opening out" of the carotid siphon by a pituitary tumour growing posteriorly and laterally, causing homonymous hemianopia.

portions are displaced laterally and forwards. The anterior cerebral arteries are displaced upwards and the angle between them and the internal carotid arteries becomes obtuse instead of being a right angle or less. These features are clearly shown in Figs. 1 and 2.

In cases of supra-sellar tumours, especially those arising from, or occupying, the jugum sellae and the posterior portion of the olfactory groove, there is little, if any, displacement of the internal carotid arteries but the anterior

FIG. 3. *Case 18.* Showing marked displacement of anterior cerebral arteries by a huge meningioma of the olfactory groove. Their curvature is now concave forwards. A faint but definite vascular pattern can be seen in the substance of the tumour.

cerebral arteries are displaced upwards and backwards to form a large curve, concave forwards instead of convex. These features are particularly well shown in Fig. 3.

In Fig. 4 they indicate that the lesion, which was clinically and radiologically a pituitary tumour, had extended forwards to occupy the olfactory groove region.

In those cases of tumours in the third ventricle in which the sella is not enlarged or eroded, the "siphon" portions of the internal carotid arteries are normal, but there are usually signs of hydrocephalus as indicated by the "opening out" of the normal curve of the anterior cerebral arteries (Fig. 5).

In other cases of tumours in the third ventricle, in which the sella is definitely enlarged and eroded, angiography shows not only the elongated

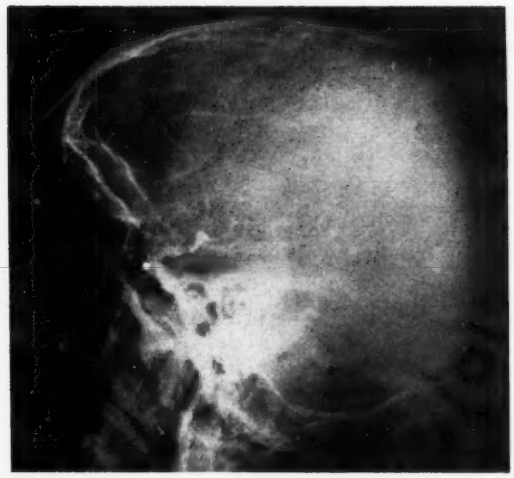


FIG. 4. *Case 8.* Pituitary tumour with erosion of sella and evidence of a large extension forwards, causing the anterior cerebral arteries to form a curve concave forwards, thus simulating a tumour of the olfactory groove. These appearances indicated that the best operative approach would be intradurally and down the middle line.

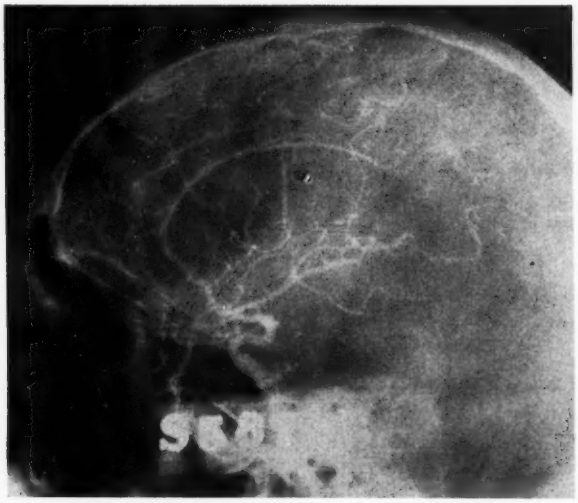


FIG. 5. *Case 14.* Third ventricle tumour (colloid cyst). There is marked "stretching" of the anterior cerebral artery caused by the enlarged lateral ventricle from hydrocephalus following a block of the foramen of Monro. The sella and the siphon are within normal limits.

anterior cerebral arteries curving around the dilated anterior horns of the ventricles (Fig. 6), but may demonstrate abnormalities in the shape and length of the "siphon," and some peculiar irregular deformities in the position of the main blood vessels (Fig. 7).

(b) *Demonstration of Pathological Circulations.* When the tumour arises from the pituitary gland, inside or outside the sella, intra-tumour circulation is rarely seen; but tumours of the olfactory groove or in the third ventricle often show the presence of a pathological circulation (Figs. 3 and 6).

(c) *Disclosure of Aneurysms.* Aneurysms of the internal carotid arteries of the circle of Willis may become large enough to erode the sella turcica and/

FIG. 6. *Case 16.* Showing marked degree of "stretching" of anterior cerebral vessels in a case of advanced internal hydrocephalus caused by a tumour blocking the posterior portion of 3rd ventricle. The faint "milky-way" outline of the vascular pattern in the tumour can just be seen, anterior and superior to the shadow of the 1 cc. myodil, held up in posterior portion of blocked 3rd ventricle. Note advanced degree of destruction of sella.

or produce bitemporal hemianopia with headaches, and thus simulate pituitary tumours. The value of angiography in this type of lesion has been referred to by Pennybacker[2] and Milletti[1] (Fig. 8). Smaller aneurysms may affect only one optic nerve and lead to unilateral atrophy and headache (Fig. 9).

(d) *Verification of the Presence of Tumours.* Pituitary adenomas and craniopharyngiomas situated above the sella turcica are often disclosed by angiography when there is no evidence of enlargement or erosion of the sella, or of supra-sellar calcification, in the plain skiagrams of the skull.

(e) *Exclusion of Tumours.* Without angiography, this may be difficult if

FIG. 7. *Case 15.* Tumour in floor of 3rd ventricle. (*Left*) Showing marked enlargement of sella, with flattened siphon and deformity of anterior cerebral artery. (*Right*) Anteroposterior view, showing marked elongation and deformity of anterior cerebral artery.

there are symptoms and signs of pituitary dysfunction, with headaches, defective visual acuity and bitemporal defects in the visual fields, and if there is enlargement and erosion of the sella, as occurred in Case 17 (Fig. 10). These symptoms and signs are often caused by chiasmal and basal arachnoiditis, and the angiograms are normal for the carotid "siphon" region, but indicate a hydrocephalic enlargement of the ventricles.

In other cases, when the sella is not enlarged and headaches are not a feature, there is less difficulty (Fig. 11).

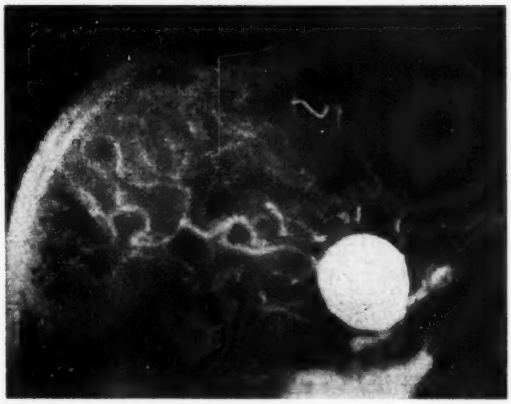


FIG. 8. Huge aneurysm of infraclinoid portion of internal carotid artery, which has eroded the sella and caused bitemporal hemianopia. (Milletti's case[1])

FIG. 9. *Case 21.* Showing a small aneurysm from terminal portion of internal carotid artery, which caused headache and homolateral optic atrophy, by displacing the optic nerve and compressing it at the optic foramen. Sella is within normal limits.

FIG. 10. *Case 17.* Showing that an advanced degree of internal hydrocephalus can cause pituitary dysfunction, headaches and field defects, with erosion of sella. The siphon and anterior cerebral artery are normal in shape and position.

FIG. 11. *Case 19.* Showing a lateral angiogram within normal limits superimposed on a pneumoencephalogram of a patient with an eroded flat sella and only a nasal field of vision in right eye, caused by chiasmal arachnoiditis.

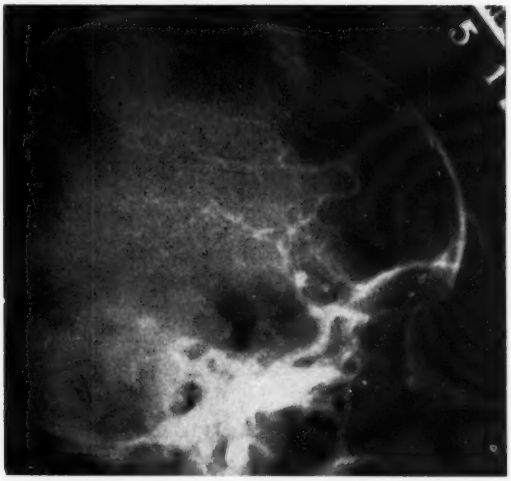


FIG. 12. *Case 10.* Marked displacement of anterior cerebral artery and "opened out" siphon in a case of pituitary tumour extending forwards as well as upwards.

FIG. 13. *Case 5.* Showing obliteration of the usual curves of the carotid siphon, and elongation of intracranial portion of internal carotid artery in a case of pituitary tumour with marked destruction of sella and a big extension laterally.

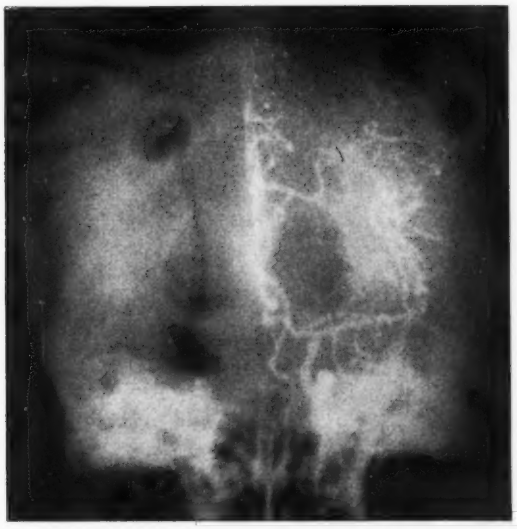


FIG. 14. *Case 1.* Postoperative angiogram of same patient as in Fig. 1, showing that the first portion of the anterior cerebral artery is now almost in its normal position.

TABLE 1

A series of 21 illustrative cases

Case No.	Sex and Age	Clinical Features	Skiagrams	Angiography	Pre-Operative Diagnosis	Operative Findings and Treatment	Postoperative Complications	Result
1	M 59	6 yrs. failing vision; blind rt. eye, only nasal field lt. eye. Marked bilat. optic atrophy, hypopituitarism	Extensive destruction of sella	Marked displacement of ant. cerebrals; elongation of carotid siphon. Figs. 1 and 14	Chromophobe adenoma	Chromophobe adenoma. Intracapsular removal	Complete blindness	Poor
2	M 52	4 yrs. headaches, failing vision. Mild endocrine disorders. Bitemp. field defects	Sl. enlarged sella; erosion lt. ant. clinoid process	Lat. displacement and "opening out" of terminal portions of lt. int. carotid	Chromophobe adenoma	Chromophobe adenoma. Subtotal intracapsular removal	Extradural haematoma; wound infection	Good
3	F 52	2 yrs. failing vision, headaches. Some endocrine symptoms. Bitemp. field defects	Markedly enlarged sella	(Postoperative) Nonfilling of lt. ant. cerebral (thrombosis)	Chromophobe adenoma	Large chromophobe adenoma. Subtotal intracapsular removal via rt. frontal approach	Rt. hemiplegia, aphasia; improved by stellate ganglion blocks	Satisfactory
4	M 58	5 mos. impaired vision, headaches. Bitemp. hemianopia	Sl. enlarged sella	Lat. displacement of terminal portion of rt. int. carotid. Bifurcation pushed upwards and outwards	Pituitary adenoma	Moderate-sized cystic and solid tumour. Intracapsular removal. Biopsy inconclusive	Nil	Good
5	F 55	Headaches for yrs., worse recently. Failing vision 9 mos. Bitemp. hemianopia	Enlarged sella	Marked lat. displacement of ant. cerebrals; elongation of carotid siphons. Fig. 13	Pituitary tumour	Moderately large pituitary adenoma. Subtotal intracapsular removal	Transient blindness rt. eye; recovery in few days. Light reflex never lost	Good. Improvement in sight
6	F 48	Headaches for yrs., worse recently. Some endocrine symptoms. Poor sight rt. eye since injury 23 yrs. ago. Failing sight lt. eye 18 mos. Bilat. optic atrophy	Enlarged sella	Marked displacement of ant. cerebrals	Pituitary tumour	Large encapsulated pituitary tumour. Intracapsular removal. Pathology unverified	Nil	Good
7	M 67	1 yr. failing vision	Markedly enlarged sella	Typical displacements of int. carotid and main arteries	Pituitary tumour	Chromophobe adenoma. Subtotal intracapsular removal	Mild frontal lobe syndrome	Good
8	M 34	3 yrs. failing vision, loss of libido. Recent lt.-sided headaches, rt. hemiparesis. Lt. optic atrophy; blind temp. field rt. eye	Moderately enlarged sella	Tumour extending into ant. fossa; angiog. guided op. approach. Fig. 4	? pituitary tumour; ? olfactory groove meningioma	Eosinophil adenoma; suprasellar and olfactory groove extensions. Bifrontal flap; removal in 2 stages	Chest complications after 1st stage	Recovery of full field rt. eye and from hemiparesis
9	M 34	3 yrs. pains in head, impaired vision to lt. side. Complete lt. homon. hemianopia	Markedly enlarged sella; destruction of floor and dorsum	Obliteration of normal curve of rt. int. carotid siphon; forward displacement of bifurcation. Fig. 2	Pituitary adenoma with extension on rt. side	Chromophobe adenoma extending lat. into middle fossa and post. on rt. side. Intracapsular removal, including extensions	6 days postop. lapsed into coma. Acute hydrocephalic block of rt. lat. vent. Relief after drainage. Temporary rt. 3rd nerve palsy	Good, but death 4 mos. later from coronary occlusion

TABLE 1 (*Continued*)

Case No.	Sex and Age	Clinical Features	Skiagrams	Angiography	Pre-Operative Diagnosis	Operative Findings and Treatment	Postoperative Complications	Result
10	M 30	1yr. failing sight; headaches, endocrine symptoms. Bitemp. hemianopia, optic atrophy. Much improved after intracapsular removal of chromophobe adenoma. 2 yrs. later, rt. hemiplegia, hemianopia; headaches, vomiting, lapsed into coma	Moderately enlarged sella; ? pineal displaced to rt.	Big upward displacement of lt. ant. cerebral and bifurcation of lt. int. carotid. Fig. 1♀	Recurrent adenoma with extension into lt. middle fossa	Large lt. frontotemporal oligodendroglioma. Removal; deep x-ray therapy	Nil	Satisfactory 2 yrs. later
11	M 45	3 yrs. headaches, failing vision. Low back pain, sciatica; ? discogenic. Lethargy, impotence, bitemp. hemianopia. Relief by intracapsular removal of pituitary adenoma. 1 yr. later, pains in back, paraplegia in flexion. Very lethargic, almost blind	Markedly destroyed sella. No osseous lesions in spine. Myelography normal	Marked displacement of ant. cerebrals; "stretching" of terminal portions of int. carotids	Chromophobe adenoma of pituitary with extension into 3rd vent.	Intracapsular removal of recurrent adenoma extending upwards and backwards to compress 3rd vent. and cerebral peduncles	Haemorrhage and hyperthermia	Death 1 day postop.
12	F 38	2 yrs. headaches, amenorrhoea, polydipsia, polyuria. Bitemp. hemianopia. Craniopharyngiomatous cyst aspirated; relief, but persistent hypopituitarism. 7 yrs. later loss of sex function, vaginal atrophy. Response to endocrine therapy. 6 mos. later failing sight, visual fields contracting. Fits, periods of coma	Sella within normal limits	Appearances of tumour arising out of pituitary fossa	Recurrence of craniopharyngioma	Cyst evacuated; cavity swabbed with Zenker's solution. Full endocrine replacement therapy continued	Became blind 4 days postop.	1 mo. later lapsed into coma; died
13	M 18	4 yrs. lassitude, headaches. Signs of hypopituitarism, immaturity. Vision not impaired	Large area of supra-sellar calcification	No displacement of int. carotids and first parts of ant. cerebrals. Remainder of ant. cerebrals displaced upwards	Craniopharyngioma	Operation not indicated. Replacement therapy	Nil	Satisfactory response
14	M 51	2 yrs. headaches, hypertension. Failing vision, papilloedema	No enlargement of sella	"Stretching" of ant. cerebral indicating int. hydrocephalus. Fig. 5	3rd vent. tumour	Torkildsen operation. 1 mo. later colloid cyst of 3rd vent. removed via transvent. approach	Nil	Satisfactory
15	M 47	For some mos., mental hebetude, headaches, "blackouts," loss of energy, incontinence. Signs of hypopituitarism and bitemp. field defects	Advanced destruction of sella, especially dorsum	Abnormal length and shape of carotid siphon. Atypical deformities of main arteries. Fig. 7	Supra-sellar tumour filling 3rd vent.	No tumour found in cavity of 3rd vent. but floor irregular and too highly vascularised for biopsy. Deep x-ray therapy given	Hypopituitary "crises" and pneumonia, relieved with cortone	Good. Field defects disappeared

TABLE 1 (*Continued*)

Case No.	Sex and Age	Clinical Features	Skiagrams	Angiography	Pre-Operative Diagnosis	Operative Findings and Treatment	Postoperative Complications	Result
16	M 16	3 yrs. hypothalamic "attacks." Recent onset headaches, vomiting, failing vision	Erosion of sella; marked "thumbing" of vault of skull	Marked "stretching" of ant. cerebral indicating int. hydrocephalus. Faint "blush" in post. part of 3rd vent. Fig. 6	Solid tumour in 3rd vent.	Piloid astrocytoma of post. part of floor of 3rd vent. Third ventriculostomy	Intravent. haemorrhage	Died 1st postop. day without regaining consciousness
17	M 45	25 yrs. earlier, "tic douloureux" successfully treated by alcohol injection of trigeminal ganglion. 6 yrs. frontal headaches. Recently biliousness, nervousness. Hypertension. Normal vision	Grossly enlarged pituitary fossa	"Stretching" of ant. cerebrals indicating int. hydrocephalus. Fig. 10	Old hydrocephalus with cerebral atrophy	Ventriculography showed gross symmetrical hydrocephalus without high intracranial pressure. No indication for operation	Fits 3 days later	Died. Autopsy: adhesive basal hydrocephalus
18	M 54	15 mos. failing vision, headache, mental changes. Lost job, began drinking heavily. Admitted to mental hosp. Transferred because CSF protein was 400 mg.%. Visual acuity much reduced	Normal sella	Ant. cerebrals elongated and "stretched" over huge tumour arising from olfactory groove. Fig. 3	Olfactory groove meningioma	Large olfactory groove meningioma of angioblastic type. Total removal in 3 stages	Nil	Good. No sign of recurrence 3½ yrs. later. Fits on occasions
19	F 38	3 yrs. blindness lt. eye after injury. 6 mos. severe lt. frontal headaches, failing vision in rt. eye. Optic atrophy lt. eye. Normal fundus rt. eye, temp. field defect	Norma sella	Lt. ant. cerebral displaced slightly upwards. Fig. 11	Small pituitary tumour	Cystic chiasmal arachnoiditis. Division of adhesions around chiasm	Nil	Slightly improved vision in rt. eye; relief of headaches
20	M 12	6 yrs. after severe attack morbilli, "short-sight," failing vision, restricted fields. Fat Fröhlich type. Hypogenitalia. Mentally retarded	Norma sella	Bilat. angiograms within normal limits	Dyspituitarism and amblyopia following encephalitis with morbilli	No operation	Nil	No change
21	F 51	2 yrs. rt. frontal headaches, diminishing vision rt. eye with optic atrophy	No abnormalities seen	Small aneurysm of supraclinoid portion of rt. int. carotid. Fig. 9	Compression of rt. optic nerve by aneurysm	Small aneurysm of rt. int. carotid; compression of rt. optic nerve. Ligature of rt. common carotid in neck; decompression of rt. optic nerve	Nil	Relief of headache but no return of vision in rt. eye

(f) *Indication of Large Extra-sellar Extensions of Pituitary Tumours.* When the extension is anteriorly, the surgeon is able to plan an approach down the middle line, after separation of the frontal lobes, in preference to the ordinary unilateral subfrontal approach (Fig. 12).

In other cases, the angiograms may show that the maximum extension of a pituitary tumour is in a lateral and upward direction, with complete obliteration of the curves of the "siphon" of the internal carotid (Fig. 13).

(g) *Postoperative Complications.* Angiography was particularly valuable in Case 3, in which a right-sided hemiplegia developed shortly after a classical right-sided subfrontal operation for a pituitary adenoma. At first it was thought that this might have been a false localising sign caused by compression of the opposite crus cerebri from an ipsilateral extradural clot, but angiography of the left carotid system revealed the presence of a thrombosis of the left anterior cerebral artery and thus saved the patient from having the wound re-opened unnecessarily.

In Case 1, total blindness followed operative removal of a large pituitary adenoma in a patient whose vision was very limited before surgery, and angiography excluded the presence of any postoperative collection of blood or fluid in the region of the optic chiasm and showed much less displacement of the main blood vessels than before operation (compare Fig. 14 with Fig. 1).

ILLUSTRATIVE CASES

During the last two years, angiography has been helpfully employed in the diagnosis of 21 cases of lesions in and around the sella turcica. Some of the features of some of these cases have already been referred to. Full details of all the cases are submitted in Table 1.

REFERENCES

1. Milletti, M. Gli aneurismi dei vasi cerebrali. Diagnostica clinica e terapia chirurgica. *Arch. Neurochir.*, 1952, *1:* 433–651.
2. Pennybacker, J. Pituitary, pineal and third ventricle tumours. *Postgrad. med. J.*, 1950, *26:* 141–155.

PERITONEAL SHUNTS IN THE TREATMENT OF HYDROCEPHALUS AND INCREASED INTRACRANIAL PRESSURE

A 4-YEAR SURVEY OF 62 PATIENTS

IRA J. JACKSON, M.D., AND S. R. SNODGRASS, M.D.
Division of Neurological Surgery, Department of Surgery, John Sealy Hospital, University of Texas, Galveston, Texas

(Received for publication December 21, 1954)

THE surgical treatment of hydrocephalus over the years has offered many procedures with varied results. As a rule the longer the follow-up, the poorer the results. It is for this reason that we wish to report our experiences with ventricular or lumbar subarachnoid peritoneal shunts in 62 patients studied over a period of 4 years at the University of Texas. Our own results at the end of a 2-year follow-up were far more favorable than this report.

The basic mechanism for the production of hydrocephalus has been for the most part an obstruction to the flow of cerebrospinal fluid or a defect in the absorptive mechanism. Therefore, the many surgical procedures tried in recent years have dealt with taking the excess cerebrospinal fluid to new absorptive sites outside the central nervous system. The great majority of these have met with failure when tested over a period of time. Nosik[14] in 1950 advocated joining the lateral ventricle to the mastoid antrum, and the early results appeared promising. However, the drawbacks are obvious, such as retrograde infection, and now the procedure is rarely employed. Utilizing the superior sagittal sinus or external jugular veins as a reservoir for the excess fluid has also failed. These functioned only as long as the pressure within the ventricles was elevated, but when the intracranial pressure became low, the veins thrombosed. Shunting fluid to the ureter was first employed by Heile[8] in 1925 and popularized by Matson[12] since 1949. A kidney is removed and the lumbar subarachnoid space is joined to the ureter by a catheter. The disadvantages as pointed out by Matson[13] include the removal of one kidney, loss of fluid and electrolytes resulting from the excretion of the spinal fluid with the urine (greatest cause of mortality), and possible retrograde infection. However, his results today are better than most, recording about two-thirds of patients improved.[9] Recently, Harsh[6] has used the peritoneal cavity as the reservoir for the excess cerebrospinal fluid by joining a catheter from the lumbar subarachnoid space or ventricles to the fimbria of the fallopian tube. However, he reported only 12 patients followed less than 1 year. Even so, only 10 patients were alive and 5 had required 2 or more operations. Ransohoff[15] has utilized the pleural cavity in 6 patients with promising results.

As early as 1898 Ferguson[5] drained the spinal fluid from the lumbar area

into the peritoneal cavity. The patient died shortly afterwards and the surgeon was of the opinion that the fatality was caused by the sudden loss of fluid. Perhaps the first recorded case of a ventriculoperitoneal shunt was performed by Kausch[11] in 1905. His patient's demise took place 17 hours later. Cushing[3] reported some success in 12 patients by allowing the excess fluid from the lumbar theca to escape and be absorbed in the retroperitoneal space. However, he discarded the procedure because several patients died of intussusception. There were sporadic reports in the literature regarding peritoneal shunts until World War I, but in the following two decades such operations were virtually abandoned. A review of this subject was published by one of us (IJJ)[10] in 1951. The peritoneal shunt for the treatment of hydrocephalus was revived by Cone[1] in 1948. Since then his experience with this procedure has been extensive, though unpublished. In 1949, Cone, Lewis, and one of us (IJJ)[2] presented a small group of hydrocephalic patients from the Montreal Neurological Institute treated by peritoneal shunts.

MATERIAL

There were 62 patients operated upon over a 4-year period. Their ages ranged from 3 days to 65 years. There were 42 infants and children, and 20 adults. The various causes of the hydrocephalus are given in Table 1.

TABLE 1

Etiology

1. Infantile (no known cause, communicating, under age of 6 months)	7
2. Inflammatory	3
3. Postinflammatory	11
4. Myelomeningoceles and encephaloceles	12
5. Aqueduct of Sylvius stenosis	4
6. Congenital septa at foramen of Magendie and Luschka	2
7. Cerebral neoplasms	9
8. Pseudo tumor cerebri	10
9. Postoperative intracranial cyst	1
10. Arterial hypertension	1
11. Subdural effusions	2
Total	62

In all instances the operation was performed to alleviate increased intracranial pressure. Diagnostic air studies were carried out in most instances to determine the degree of hydrocephalus, anatomical location of the cerebrospinal fluid block, and consideration of a space-occupying lesion. When the air study did not give sufficient information to determine whether the hydrocephalus was of a communicating or noncommunicating variety, indigo carmine was introduced into the lateral ventricle and an attempt was made to recover it within 20 minutes from the lumbar spinal canal. If no dye was found in the lumbar theca at this time, we considered that we were dealing with a noncommunicating type.

SURGICAL PROCEDURES

Ventriculoperitoneal Shunt. Under general anesthesia with the patient supine and his head turned far to the left, a 5-cm. incision is made in the scalp above and behind the ear on the right side. A burr hole is made and then a needle is introduced into the lateral ventricle. Only the amount of fluid necessary to determine if the needle is in the ventricle is allowed to escape. The needle is then withdrawn and a plastic tube with several side vents is introduced through the cerebral tissue into the ventricle. The tube is transfixed at this site by passing a fine wire suture through the tube and the dura mater. We have previously placed a rubber cuff snugly around the plastic catheter and sutured it to a small hole made in the skull. However, the plastic tube changes its diameter and becomes smaller after being exposed to the body tissues and then the rubber cuff no longer holds the tube in place. The tube is then passed subcutaneously downwards on the anterior surface of the trunk to the lower abdominal quadrant by means of a long uterine forceps. It is necessary to make several small skin incisions on the trunk and thread the tube since the forceps are never long enough to reach the abdominal cavity without such interruptions. In the last 18 months we have passed the catheter only as far down as the last rib and then opened the peritoneal cavity over the liver. The tube is placed over the dome of the liver and secured to the falciform ligament by a suture. When we placed the tube in the lower abdominal cavity, a small muscle-splitting incision was employed. After the peritoneum was opened, the tube was passed down along the anterior wall in the lower quadrant away from the omentum. The tube is transfixed to the undersurface of the peritoneum by a suture. All wounds are closed with interrupted sutures in the usual fashion.

Lumbar-peritoneal Shunt. (1) *Open method.* Under general anesthesia the patient is placed in the lateral semiflexed position with the left side up. A small midlumbar incision is made and the muscles over the lamina are stripped away only on one side. A hemilaminectomy is carried out removing two laminae. While opening the dura mater every effort is made not to cut the arachnoid with the same incision. The arachnoid will usually bulge. Then with a pair of small forceps, the arachnoid is grasped and cut with a knife only enough to permit entrance of the catheter into the subarachnoid space. The catheter with several side vents at its tip is directed caudally. The tube is transfixed to the undersurface of the dura mater. One must be absolutely certain that the catheter is in the subarachnoid space and not the subdural space. The free end of the tube is then passed subcutaneously around the trunk to the left lower abdominal quadrant by means of a long uterine forceps. A small oblique muscle-splitting incision is made and the abdominal portion of the operation is the same as described above. The curve of the tube around the trunk must be smooth without any sharp angles. For the past 18 months we have passed the catheter to the suprahepatic region as described above.

(2) *Closed (needle) method.* This procedure, suggested to us by Dr. George Ehni, varies from the open lumbar shunt only in that a hemilaminectomy is not done. Instead, a very small skin incision is made overlying the midlumbar area. A number 13 Touhy spinal needle is inserted between the spinous processes into the subarachnoid space with the curved bevel pointing caudally. The stylet is withdrawn and if properly placed the spinal fluid will come out under pressure. The catheter is inserted through the needle into the subarachnoid space. The needle is withdrawn and the other end of the catheter is passed subcutaneously to either the suprahepatic region or the lower abdominal quadrant. The abdominal procedures are the same as de-

scribed above. Since the tube used for the closed method has a considerably small lumen, caution must be exerted in avoiding any kinks in the tube. The closed or needle method has not been employed with infants because of the smallness of the subarachnoid space as compared to the length of the bevel in these needles.

COMPLICATIONS

The complications were many and varied. The most frequent complication was the blockage of the tube within the abdominal cavity by either omentum or scar tissue. In one patient a huge omental cyst formed around the tip of the catheter. Of course, the tube was also blocked in the ventricle and in the lumbar subarachnoid space. When the obstruction was within the cranial portion of the tube, the opening was usually filled with a small amount of cerebral tissue.

Adhesive arachnoiditis in the lumbar theca was more common than in the early years of the operations. It was our impression that in some patients the response to foreign bodies was so much greater than in others. In several patients with long and successful follow-ups, periodic pain in the legs has been observed.

Kinking of the tube was frequently noted. This occurred more often with either the thin-walled plastic tubes or the very small-caliber tubes and almost always within the abdominal cavity. The tubes have slipped out of the lumbar canal, peritoneal cavity, and the ventricle. We have observed catheters to have migrated completely within the abdominal cavity and even within the ventricle. When the soft plastic catheter (portex) was used, four had broken at the entrance to the abdominal cavity some 4 to 12 months after surgery. This type of tubing is quite soft because of the plasticizer, but within a few weeks of contact with body fluids, it becomes rather rigid.

Hypotensive headaches were observed in many of the children and adults, but the patients soon were asymptomatic as they became adjusted to the low intracranial pressure.

Postoperative infection along the tubes subcutaneously did occur in about 6 patients who underwent more than two shunts.

The smaller infants exhibited abdominal distention for the first few postoperative days.

In carrying out the closed or needle type of lumbar subarachnoid peritoneal shunt the placement of the catheter in the subdural space took place once. We believe that when several attempts are made with the needle to enter the subarachnoid space, thereby tearing the arachnoid, the tube may pass subdurally.

Seizures have occurred in several patients during the first few days after ventriculoperitoneal shunts but have subsided with no further attacks or anticonvulsant medication after leaving the hospital.

RESULTS

We performed 116 operations on 62 patients. The reoperations were done because of recurrence of initial symptoms indicating the tube was no longer

functioning. One of the above complications was found to be the cause of the recurring symptoms. Fifty ventriculoperitoneal shunts and 62 lumbar subarachnoid peritoneal shunts were done. Of the 62 lumbar shunts, 50 were of the open type and 12 of the closed or needle type. Three procedures consisted of placing the catheter in the intracranial subdural space in order to drain an existing subdural effusion into the peritoneal cavity. These 2 patients had previously been treated for their subdural effusions by craniotomy but the brains did not expand to obliterate the dead space. Therefore, they continued to collect subdural fluid. As a means of preventing enlarge-

TABLE 2

Results

Patients alive—no increased intracranial pressure			22
Patients alive—with increased intracranial pressure			7
Patients dead—result of increased intracranial pressure			20
Patients dead—no evidence of increased intracranial pressure at death			12
Causes of death:			
encephalitis	—	1	
original infection	—	1	
meningitis	—	1	
tuberculosis	—	1	
pneumonia	—	2	
cause unknown—sudden	—	3	
Goldblatt kidney	—	1	
brain stem neoplasm	—	1	
cerebral thrombosis	—	1	
No follow-up			1
Total			62

ment of the cranial vault, this type of shunt was done. In 1 infant the shunt was successful in that the size of head remained small. The patient became a microcephalic with marked mental retardation because of the severe cerebral scarring. In another patient, the tube was placed in the tumor cyst and drained to the peritoneal cavity, but this was unsuccessful.

At the end of 4 years, we have only 22 patients alive without increased intracranial pressure (Table 2). Seven more patients are alive, but have increased intracranial pressure following one or more shunting procedures. Twenty patients have died with increased intracranial pressure, but none as a direct result of the operative procedure. Twelve other patients have died but without increased intracranial pressure. The causes of death in these 12 cases were: encephalitis (1), original infection (1), meningitis (1), tuberculosis (1), pneumonia (2), Goldblatt kidney (1), brain stem neoplasm (1), cerebral thrombosis (1), and sudden unknown cause (3). In 1 case we have no follow-up.

Our more successful shunts were in patients with a diagnosis of infantile hydrocephalus or pseudo tumor cerebri. It is certainly possible in these two groups that spontaneous remissions do occur.

We have only 24 patients whose shunt functioned for over a year (Table

3). The longest duration a single shunt has functioned has been 4 years, but in only 1 patient. The cause of the hydrocephalus in this woman was probably postinfectious. We have one patient $3\frac{1}{2}$ years postoperatively with a diagnosis of pseudo tumor cerebri. Four patients have tubes functioning 3 years. In 2 of these 4 cases the diagnosis was pseudo tumor cerebri, in 1, cerebral tumor and in 1, infantile. Eleven other patients have tubes functioning over 2 years. Of these cases 3 were diagnosed as infantile, 2 pseudo tumor, 2 cerebral neoplasm, and 1 congenital septa at foramen of Magendie, 2 myelomeningocele, and 1 encephalocele.

TABLE 3

Peritoneal shunts functioning one or more years

Etiology	Years
1. Postinfections	4
2. Postinfections	1
3. Infantile	3
4. Infantile	2, $2\frac{1}{2}$*
5. Infantile	2, $2\frac{1}{2}$*
6. Infantile	2, $1\frac{1}{2}$*
7. Pseudo tumor cerebri	1
8. Pseudo tumor cerebri	$1\frac{1}{2}$
9. Pseudo tumor cerebri	2
10. Pseudo tumor cerebri	2
11. Pseudo tumor cerebri	3
12. Pseudo tumor cerebri	3
13. Pseudo tumor cerebri	$3\frac{1}{2}$
14. Aqueduct gliosis	$1\frac{1}{2}$
15. Aqueduct gliosis	1
16. Occlusion of foramen of Magendie and Luschka	$1\frac{1}{2}$
17. Occlusion of foramen of Magendie and Luschka	2
18. Myelomeningocele	2
19. Myelomeningocele	$2\frac{1}{2}$
20. Myelomeningocele	1
21. Encephalocele	2
22. Cerebral neoplasm	2
23. Cerebral neoplasm	2
24. Cerebral neoplasm	3

* Two operations—each functioning specified number of years.

In some patients several years after their shunting procedure, we have evidence that their tube was working and necessary for their life. On the other hand we have some cases in which it is quite obvious that the catheter is no longer working nor is it now necessary for the patient's healthy existence. Three infants with the diagnosis of infantile hydrocephalus returned to the hospital 2 years after their first shunting operation with vomiting, drowsiness, and papilledema. A second procedure was done since they had obviously outgrown their original catheter and they have now been followed for $1\frac{1}{2}$ to $2\frac{1}{2}$ years without any recurrence of symptoms. There were 2 infants with repaired myelomeningoceles as the cause of their hydrocephalus. They were treated with ventriculoperitoneal shunts, and at the

end of 2 and 2½ years they are exhibiting no symptoms of increased pressure, but it is apparent by their body growth that the tube is no longer necessary or effective. The plastic catheters do not stretch as the body grows. It would appear, then, that there are some patients with increased intracranial pressure who need only a temporizing procedure and soon are able to absorb their cerebrospinal fluid to a sufficient degree.

SUMMARY

Over a 4-year period 62 patients, aged 3 days to 65 years, were treated for increased intracranial pressure by means of 62 ventriculoperitoneal shunts and 50 lumbar subarachnoid peritoneal shunts. There were 42 patients up to the age of 14 years, and 20 were older.

This study reveals that only about 39 per cent of the patients were benefited over a long period of time by the procedures. Only 2 patients in this group of successful shunts are not leading useful or relatively normal existences.

The surgical technique and complications are presented.

To fully evaluate any surgical operation for the treatment of hydrocephalus or increased intracranial pressure, a period of years must pass by. Our own experience with peritoneal shunts has shown us that the longer one follows these patients the poorer are the long-term results. However, we do feel that these shunts have a limited value in the neurosurgeon's armamentarium.

REFERENCES

1. Cone, W. V. Personal communication, 1949.
2. Cone, W. V., Lewis, R. D., and Jackson, I. J. Shunting of cerebrospinal fluid into the peritoneal cavity. Presented at meeting of American College of Physicians, Montreal, Canada, Sept. 23, 1949.
3. Cushing, H. Studies in intracranial physiology and surgery. The third circulation. The hypophysis. The gliomas. *London: Humphrey Milford, Oxford Univ. Press*, 1926, xii, 146 pp. (see pp. 7–11).
4. Davidoff, L. M. Treatment of hydrocephalus. Historical review and description of a new method. *Arch. Surg., Chicago*, 1929, *18:* 1737–1762.
5. Ferguson, A. H. Cited by Davidoff.[4]
6. Harsh, G. R., III. Peritoneal shunt for hydrocephalus utilizing the fimbria of the fallopian tube for entrance to the peritoneal cavity. *J. Neurosurg.*, 1954, *11:* 284–294.
7. Haynes, I. S. Congenital internal hydrocephalus. Its treatment by drainage of the cisterna magna into the cranial sinuses. *Ann. Surg.*, 1913, *57:* 449–484.
8. Heile. Über neue operative Wege zur Druckentlastung bei angeborenem Hydrocephalus (Ureter-Duraanastomose). *Zbl. Chir.*, 1925, *52:* 2229–2236.
9. Ingraham, F. D., and Matson, D. D. Neurosurgery of infancy and childhood. *Springfield, Ill.: Charles C Thomas*, 1954, xvii, 456 pp. (see p. 147).
10. Jackson, I. J. A review of the surgical treatment of internal hydrocephalus. *J. Pediat.*, 1951, *38:* 251–258.
11. Kausch, W. Cited by Haynes.[7]
12. Matson, D. D. A new operation for the treatment of communicating hydrocephalus. Report of a case secondary to generalized meningitis. *J. Neurosurg.*, 1949, *6:* 238–247.
13. Matson, D. D. Hydrocephalus treated by arachnoid-ureterostomy. Report of 50 cases. *Pediatrics*, 1953, *12:* 326–334.
14. Nosik, W. A. Ventriculomastoidostomy. Technique and observations. *J. Neurosurg.*, 1950, *7:* 236–239.
15. Ransohoff, J. Ventriculo-pleural anastomosis in treatment of midline obstructional neoplasms. *J. Neurosurg.*, 1954, *11:* 295–298.

A NOTE ON THE USE OF 25 PER CENT IODOPYRACET (DIODRAST) IN CEREBRAL ANGIOGRAPHY

D. L. SUTHERLAND, M.D., WILLIAM C. KITE, JR., M.D.
J. F. ROACH, M.D., AND ELDRIDGE CAMPBELL, M.D.
Departments of Surgery and Radiology, Albany Medical College, Albany, New York

(Received for publication January 10, 1955)

IN A recent article[3] the complications that followed the employment of 35 per cent Iodopyracet (Diodrast) in cerebral angiography were recorded in a series of 234 examinations at the Albany Hospital. Evanescent neurological changes were noted in 11.5 per cent while major sequelae were encountered in 4.3 per cent. That this experience was not unusual is suggested by the papers of Dunsmore, Scoville and Whitcomb,[1] Rowbotham *et al.*[4] and others.

That 30 per cent Urokon is not entirely safe is evidenced by the experience of Seaman and Schwartz.[5] On the other hand, Lin, Murtagh, Wycis and Scott[2] had but one complication when employing a technique that required but a single 8 to 10 cc. injection of 30 per cent Urokon sodium.

In searching for a safer material that would afford satisfactory contrast the suggestion was made that 25 per cent rather than 35 per cent Iodopyracet (Diodrast) be given a trial.* It was pointed out that the former solution was more nearly isotonic albeit the iodine content was definitely reduced.† This report concerns our experience with 108 consecutive cerebral and vertebral angiograms in which 30 to 40 cc. of 25 per cent Iodopyracet (Diodrast) were employed. The patients ranged from 18 to 56 years in age. While the contrast has not been ideal in every instance, it has been adequate in all but a few, and has proved itself a far safer medium.

An evaluation of the technical adequacy of 25 per cent versus 35 per cent Iodopyracet (Diodrast) was made by comparing the angiographic films of 25 consecutive cases in each of the two groups.

In each group there were 4 unsatisfactory examinations. Of these, 6 were the result of poor x-ray technique and 2 were brought about by incorrect positioning of the needle tip. Of the angiograms in the remaining 21 cases in each category, 7 were considered to be of "fair" diagnostic quality and the rest were classified as "good." The "good" angiograms in each series were carefully contrasted. It was apparent in the 25 per cent group that the radiographic density of the vessels as they traversed the base of the skull was not as great as one might have desired. However, there was no significant differ-

* This we owe to Dr. J. B. Rice, Director of Medical Research, Winthrop Stearns, Inc., 1450 Broadway, New York, New York.

† The tonicity of the 25 per cent solution is 2½ times that of plasma while the 35 per cent solution is 3½ times.

ence in the delineation of pathologic changes throughout both carotid and vertebral trees.

COMPLICATIONS

There was no instance in which death was seemingly hastened by angiography although 12 patients are known to have expired subsequently from progression of their diseases. In one individual, marked spasm of the right internal carotid artery was noted at operation a few hours after angiography. This patient had an aneurysm of the anterior communicating artery. One can only speculate on the relationship between the angiography and the arterial spasm, in view of the proximity of the aneurysm and its recent rupture. In another patient, who suffered from subarachnoid hemorrhage, aphasia and right hemiplegia developed several hours following right common carotid angiography. It had been known that this man's condition was deteriorating at the time the examination was carried out (see below). A third patient reported transient paresthesia of the left hand at the time of right carotid angiography.

Following is a summary of the one case in which a severe complication occurred which was possibly, but not probably, related to angiography.

W. R., an 18-year-old mail clerk, was admitted to the Albany Hospital with a history of headache commencing the previous day. Transient weakness of the right arm had been noted. He became disoriented and nuchal rigidity developed. His past history revealed several similar episodes, the last one having been 3 years previously.

Examination disclosed slight increase in the tendon reflexes on the right. Xanthochromic fluid was found on lumbar puncture. A left carotid angiogram proved negative. The right carotid was injected the following day at a time when the patient's condition was deteriorating. Shortly afterwards right spastic hemiplegia and aphasia developed. It was thought probable that further bleeding had taken place from an unfilled aneurysm on the left side of the circle of Willis.

After a stormy course, the patient gradually improved and was discharged after 1 month in the hospital, still aphasic, but improving.

While the right hemiplegia appeared the day following the left carotid injection and was probably not a direct complication, it is felt that the above case should be recorded for sake of completeness.

Another factor that has probably contributed to lowering the morbidity in the cases in which 25 per cent Iodopyracet (Diodrast) was employed was the greater technical skill of the operators. By and large, the arteries were punctured with more ease and consequently with less trauma to the vessel walls. Repeated injections were less frequently required because of the use of the Fairchild camera.

However, both of these considerations apply to the latter half of our first series[3] in which 35 per cent Iodopyracet (Diodrast) was employed. When the change was made to the 25 per cent solution the lowered incidence of complications was quite striking.

In round figures it may be said that there were major and minor complications in approximately 16 per cent following the 234 angiograms in which 35 per cent Iodopyracet (Diodrast) was employed, while less than 2 per cent occurred following the use of 25 per cent solution.

The reduction of the strength of Iodopyracet (Diodrast) from 35 per cent to 25 per cent affects its value as a contrast medium but little. No difficulty in visualizing the finer branches of the carotid or basilar tree was encountered with the weaker solution.

SUMMARY AND CONCLUSIONS

1. In endeavoring to find a safer contrast medium for carotid angiography, 25 per cent Iodopyracet (Diodrast) has been used in 108 angiograms in 87 patients.

2. Satisfactory angiograms were obtained with solutions of this strength.

3. A significant reduction in the number of complications was noted. Only 2 could possibly have been attributed to the use of the 25 per cent solution of this material.

4. These results compared favorably with an incidence of approximately 16 per cent major and minor neurological sequelae when the 35 per cent solution was previously employed.

REFERENCES

1. Dunsmore, R., Scoville, W.B., and Whitcomb, B.B. Complications of angiography. *J. Neurosurg.*, 1951, *8:* 110–118.
2. Lin, P., Murtagh, F., Wycis, H., and Scott, M. Carotid angiography with Urokon, using the Chamberlain bi-plane stereoscopic angiographic unit. Report of one hundred cases. *J. Neurosurg.*, 1953, *10:* 367–372.
3. Perese, D. M., Kite, W. C., Bedell, A. J., and Campbell, E. Complications following cerebral angiography. *Arch. Neurol. Psychiat., Chicago*, 1954, *71:* 105–113.
4. Rowbotham, G. F., Hay, R. K., Kirby, A. R., Tomlinson, B. E., and Bousfield, M. E. Technique and the dangers of cerebral angiography. *J. Neurosurg.*, 1953, *10:* 602–607.
5. Seaman, W. B., and Schwartz, H. G. Clinical experience with Urokon sodium 30 per cent (pH 7) for cerebral arteriography. *J. Missouri med. Ass.*, 1952, *49:* 553–554.

CIRCUMVENTION OF ANOXIA DURING ARREST OF CEREBRAL CIRCULATION FOR INTRACRANIAL SURGERY

W. M. LOUGHEED, M.D.,* AND D. S. KAHN, M.D.
Neurosurgical Service, Massachusetts General Hospital, Boston, Massachusetts

(Received for publication January 24, 1955)

Comparison of Shunts and of Local and Systemic Hypothermia. Effect of Hypothermia on Cerebral Metabolic Rate and Cerebral Tolerance to Anoxia. Vascular lesions of the brain could be treated more adequately if the blood supply to the affected area were occluded or at least diminished. This necessitates supplying the brain distal to the lesion with arterial blood or protecting it from anoxia. In searching for a method to facilitate the neurosurgical approach to these lesions of the brain, we first tried in dogs various kinds of polyethylene shunts and perfusion pumps to deliver arterial blood to the brain distal to points of occlusion of its trunk arteries. The disadvantages proved so great that we moved to a study in dogs of hypothermia, which we now consider the method of choice.

Since Bigelow[2–4] first suggested the use of hypothermia for cardiac surgery there has been an ever increasing interest in this field. Bigelow, Lewis and Taufic[17] and Swan *et al.*[25] have demonstrated conclusively the protection it affords both the heart and the brain during circulatory arrest.

POLYETHYLENE SHUNTS AND PERFUSION PUMPS

Polyethylene shunts varying from 0.5 to 2.0 mm. in diameter were used. In order to test them easily, the superficial femoral artery was occluded by a bulldog clamp and the artery was cannulated above and below the point of occlusion with this polyethylene tubing. The occurrence of thrombosis in all preparations was the prime factor in the failure of these shunts. The time interval before thrombosis occurred usually varied between 5 and 10 min.; only an occasional shunt lasted longer. Unless a flow meter is available for continuous observation of blood flow, the occurrence and site of thrombosis in the shunt are not detectable and represent a great danger and inconvenience. It was proposed to use these shunts for lesions of the middle cerebral artery. The external carotid artery was cannulated with polyethylene tubing and the shunt was then carried externally around the head and inserted into one of the branches of the middle cerebral artery. We found, however, that it was impossible to cannulate the cerebral vessels with a mere tip of polyethylene, and so mounted a #22 needle, which had been especially ground on its outside diameter, on the end of the polyethylene shunt. The needle on this end even though siliconed acts as a nidus for thrombosis. These small shunts deliver only a small amount of blood, and they are very difficult to maintain in place.

* *Present address*: Toronto General Hospital, Toronto, Ontario.

It was decided to increase the pressure of the blood in order to increase the rate of circulation. A simple perfusion pump was built to do this. It consisted of two 500 cc. bottles arranged in such a way that the arterial blood could flow into one bottle (from a cannula in the carotid) while arterial blood previously collected could be forced into the cerebral artery by oxygen pressure delivered to the bottle that was perfusing the blood (Fig. 2). The cannula receiving the blood from the animal had a double barrel, so that citrate could be mixed with the blood as it entered the pump.

By this method we were able to perfuse the area of brain that had its blood supply isolated, but it was very difficult to insert a cannula in the small branches of the middle cerebral artery and even harder to maintain it in place, for the slightest movement resulted in tearing of the small branch out of its bed. We, therefore, concluded that the above methods present three disadvantages, in that:

1) The use of anticoagulants is contraindicated during neurosurgical procedures.

2) The preparation of the extracorporeal circulation becomes an operation in itself before a lengthy neurosurgical operation is embarked upon.

3) The large blood vessels of the brain do not have sufficient collateral circulation to allow them to be sacrificed for cannulation. Therefore, it is necessary to cannulate a small cerebral artery. This reduces the quantity of blood that can be perfused through the isolated portion of the brain. These small vessels are very delicate and it is difficult to maintain the cannula in place. For the above reasons we have given up these approaches for the simpler and more feasible one of hypothermia.

HYPOTHERMIA

Prior to a discussion of the advantages of hypothermia, it is essential to be aware of its dangers and disadvantages. The primary dangers of hypothermia are ventricular fibrillation and cardiac failure. As a part of this investigation, studies of the cardiac output, mean femoral and pulmonary arterial pressures, and mean right and left auricular pressures were done, from which calculations of the total pulmonary and peripheral resistance and the right and left ventricular stroke works were made. The electrocardiogram was recorded at sampling intervals. These findings will be reported separately. It is sufficient to state here that ventricular fibrillation did not occur in this series of dogs at temperatures above 25°C. (excluding local hypothermia). Below 25°C. there were 3 dogs out of 15 that died from fibrillation. Our findings agree with those of Clark[8] and Starling *et al.*[18,21,22] The latter said:

". . . the minimum temperature at which the mammalian heart can beat against what may be called an average resistance varies between 23° and 26°C. As the heart is gradually cooled, when the critical temperature is reached, it suddenly dilates, the output diminishes rapidly, and unless the arterial resistance is relaxed and the blood warmed quickly, the heart ceases to beat, often going into fibrillary

contraction. . . . In the case of a heart embarrassed by a cardiometer, the critical temperature was 26°C. In other cases, it was as low as 23°C. When the arterial pressure is relaxed as the heart is cooled, it may go on beating more and more slowly and fully until a lower temperature is reached . . . flow through the coronary vessels varied very little with alteration in the temperature, being somewhat greater at a low temperature (below 28°C.). In view of the extreme susceptibility of the coronary vessels to locally produced metabolites, it seems possible that this dilatation at low temperatures may be due to a slowing of the process of oxidation. Partially oxidized metabolites may escape the cells and exert a dilating influence on the coronary vessels."

It is thus realized from Starling's observations that ventricular fibrillation may signify a terminal event in cardiac failure occurring at temperatures below 25°C. Ventricular fibrillation at this low temperature occurs at a time when the contractility of the ventricle is diminished, and after defibrillatory procedures, ventricular contractions may not resume.

In addition to the above-mentioned mechanism, ventricular fibrillation has been reported to occur during cooling or rewarming at temperatures higher than those required to limit effective ventricular contractility. The factors responsible have not been clarified. Hegnauer *et al.*[14] have shown that fatal ventricular arrhythmias from intraventricular catheters occur in 80 to 85 per cent of cooled animals. Hoff and Stansfield[15] reported that cooling of one portion of the ventricle makes the heart susceptible to fibrillation by a single shock applied anywhere in the non-cooled portion of the ventricle. Swan *et al.*[25] as well as Brown, Miller *et al.*[5,19] have indicated that sudden changes in pH and carbon-dioxide tension with changes in the serum potassium may precipitate ventricular fibrillation. Wégria *et al.*[27] have demonstrated that slowing of the heart rate per se with consequent increase in the relative refractory period will render the heart more susceptible to arrhythmias from ectopic ventricular foci. Patterson, Piper and Starling[21] emphasized that the rate of the beat of the isolated mammalian heart is directly proportional to the temperature. Clark[8] has shown that vagal stimulation in the frog results in more prolonged asystole at 18°C. than at 28 to 35°C. The effects of vagal stimulation may be potentiated and prolonged by a decrease in the blood pH, as demonstrated by Campbell *et al.*,[6] and have been attributed to a decrease in cholinesterase activity at low blood pH. Cholinesterase activity decreases in vitro with lowering of the temperature. Specific information is not available in the intact cooled animal to quantitate the possible role that acetylcholine may play in the slowing of the heart rate or in occurrence of ventricular arrhythmias.

Although the mechanism or mechanisms of ventricular fibrillation during hypothermia are not clearly defined, it is believed at present that reduction in the body temperature should ideally not exceed 25°C., a temperature that allows the maximum reduction in the cerebral metabolic rate with minimum reduction in the ventricular contractile force.

Fibrillation presents more of a problem to the cardiac surgeon than to the

neurosurgeon because the cold heart is more susceptible than a warm one to the stimulation that must occur during cardiac surgery. It seemed reasonable that two methods of approach to hypothermia were available: (1) Local hypothermia of the brain or (2) systemic hypothermia. It was reasoned that local hypothermia would eliminate the problem of fibrillation.

LOCAL HYPOTHERMIA

Method (Figs. 1 and 2). Dogs weighing 11–17 kg. were anaesthetized with pentobarbital sodium (30 mg./kg.). Through a thyroid incision the blood supply to the head was isolated, except for the anterior spinal arteries. The external carotid arteries were ligated. A perfusion pump was then connected with the proximal and distal segments of one carotid artery. The pump consists of two 500 cc. bottles arranged in such a way that the arterial blood can flow into one bottle (from the cannula in the carotid) while arterial blood previously collected (in the second bottle)

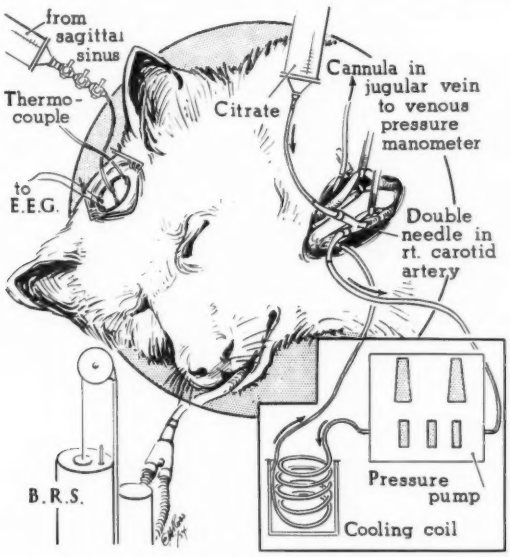


FIG. 1. "Y" cannula in right common carotid artery, and bulldog clamps on left common carotid artery and both vertebral arteries.

may be forced out into the cephalad cannula by oxygen pressure. The blood leaving the pump was passed through an ice-water bath and cooled to between 12 and 9°C. prior to entering the carotid artery. When the pump was started, the blood supply, save for the anterior spinal arteries, was then occluded. By this method the brain temperature could be lowered in 15 to 20 min. to 20°C. and in one animal it was lowered to 15°C. The brain temperature was measured by a thermocouple, which was inserted into the cerebral hemisphere contralateral to the side of the perfusion. Thermocouples were inserted in the inflow and outflow of the pump and in the rectum.

This experiment was carried out on 6 dogs and all of the animals except 1 died of ventricular fibrillation. In 2 of these dogs the probable explanation for fibrillation was air embolism. The rate of flow through the pump and brain averaged 66 cc./min. This rate was not rapid enough in 15 min. to lower the animal's total body temperature as in Delorme's[10] work; however, the blood returning to the pump from the body was usually 7 to 10°C. lower than the body temperature. During the 15 to 20 min. that was required to

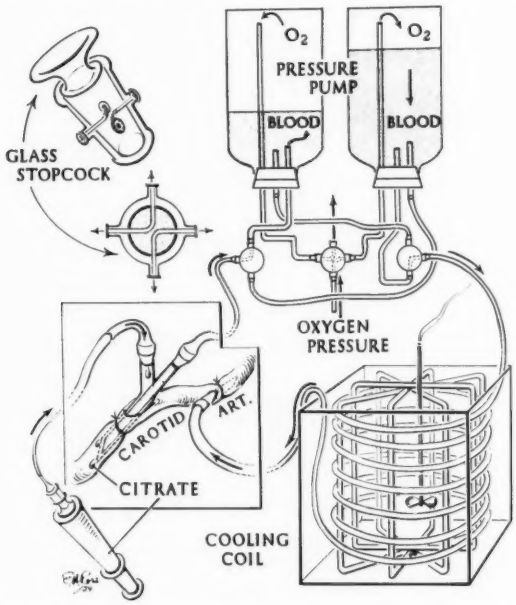


FIG. 2. "Y" cannula directed towards the heart. Single cannula directed cephalad.

lower the brain temperature to 20°C., the body temperature of the animal was lowered from 39 to approximately 35°C. The blood returning to the external pump had come from the left heart; its temperature measured at the pump was usually 7 to 10° lower than the body temperature. One might, therefore, conclude that the heart was receiving very cold blood from the brain so that we were not only cooling the brain, but also lowering the temperature of the myocardium. Perhaps the cold stream of venous blood returning from the brain to the heart may have set up a myocardial temperature differential. This might be comparable then to the experiments of Hoff and Stansfield[15] vide supra, and therefore explain the fibrillation. The actual temperature of the myocardium (assuming that it were the same as the temperature of the blood leaving the left ventricle) was never below 32 to 33°C. This temperature is much higher than the temperature at which

fibrillation is usually seen when systemic hypothermia is practised and, therefore, we assume that special susceptibility to fibrillation of non-cooled portions of the irregularly cooled ventricles occurred here. During these experiments cerebral arterial and venous oxygen[26] determinations, and those of serum lactate,[1] pyruvate,[13] hemoglobin[12] and sugar [20] were performed at various temperatures; these will be discussed together with samples taken under systemic hypothermia. Regional hypothermia has been given up until we discover the factors initiating the fibrillation in this perfusion system. Since this work was done Jensen and Parkins[16] have reported lowering the dog's brain to 20°C. by a similar technique, the while provoking a "low incidence of spontaneous cardiac arrhythmias." From their brief report we are uncertain as to the reason for our discrepant results on this score.

SYSTEMIC HYPOTHERMIA

Method. Systemic hypothermia is more practical than the above techniques because of the simplicity of the procedure. Mongrel dogs were anaesthetized either with pentobarbital sodium or with thiopental sodium. Pentobarbital was given intravenously in amounts equivalent to 30 mg./kg. body weight and thiopental sodium in amounts varying from 500 to 800 mg./animal. The femoral artery was cannulated and a trephine opening was made over the posterior aspect of the sagittal sinus. This sinus was also cannulated, electroencephalographic electrodes were placed on the dura mater, and a thermocouple was buried in the cerebral hemisphere (Fig. 1). The body temperature was recorded by thermocouples in muscle and rectum. A centigrade thermometer was placed in the rectum. An electrocardiogram was taken. As in the animals with local cerebral hypothermia we carried out determinations of arterial and venous oxygen content, and of serum lactate, pyruvate, and glucose. On some of the animals the total body oxygen consumption, cardiac output, total serum CO_2,[26] pH, hematocrit, sodium, potassium, and amino acid nitrogen[9] were also measured. The animal was rendered anoxic at normal body temperature for 2–3 min. by clamping his airway or by ventilation with nitrogen, and blood samples were again taken. The animal was then placed in the ice-water bath and cooled. Similar data were collected at various temperatures. At 25°C. the animals were again rendered anoxic.

TOLERANCE TO ANOXIA

The above method was designed in an attempt to measure the animals' tolerance to anoxia during hypothermia at 25°C. It was felt that if one could calculate the percentage reduction of the cerebral metabolic rate at 25°C., then one might predict the length of time that anoxia could be tolerated. Having once made this prediction, it could be tested by biochemical changes, survival studies, electroencephalographic recordings, and pathological sections.

1) *Biochemical Changes.* (a) *A-V Oxygen Difference.* The figures for differences between arterial and venous oxygen content, whether obtained under regional hypothermia (with controlled blood flow) or under systemic hypothermia, tended to parallel each other (Table 1). The differences were less during hypothermia but those during local hypothermia tended to be

TABLE 1

Cerebral A-V O_2 differences in hypothermia

Dog	Temperatures—Degrees Centigrade				
	38°	35°	30°	25°	22°
	Regional				
14	7.4				3.2
16	5.3		5.7	2.2	
17	15.1	11.2	5.7	7.1	
18	7.0	5.0	4.8	2.6	
19	10.5	7.4	5.0	4.1	
	Systemic				
28	7.4		6.3	3.6	
30	8.9		9.5		
32	9.9		7.3	6.6	
33	9.8		12.0	7.1	

more striking because the blood flow was kept constant and did not decrease with the temperature. The reduction in cerebral oxygen consumption (Fig. 3) either represents a reduction in the cerebral metabolic rate or, because of a leftward shift of the oxygen dissociation curve in the direction of a lower partial pressure of oxygen, an inability of the brain to extract oxygen from the blood at lowered temperatures. If the latter were true, then evidences of anoxia should be observed in the electroencephalogram, electrocardiogram,

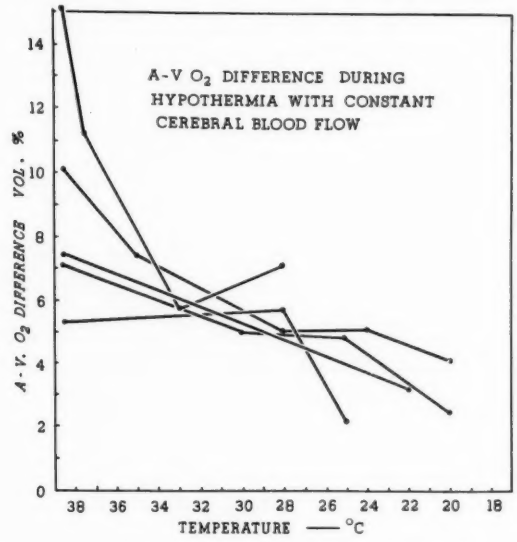


FIG. 3. A-V O_2 difference during hypothermia shows the progressive reduction in O_2 uptake with increasing depth of hypothermia.

other biochemical tests, pathological sections and an increased oxygen uptake on rewarming. It will be shown later that all the above-mentioned tests support each other in indicating that no cerebral anoxia existed. Furthermore Penrod's[23] demonstration of normal coronary A-V oxygen differences in dogs at 20°C. is additional evidence that the leftward shift of the hemoglobin dissociation curve in the cold produces no cardiac hypoxia.

The total body oxygen consumptions were also measured and these show a progressive fall as the temperature is reduced. They tend to parallel the reduction in cerebral oxygen consumption and the cerebral metabolic rate, providing there is no shivering. Fig. 4 shows representative samples. Shivering will cause the total body oxygen consumption to rise but will not affect the cerebral oxygen consumption. Therefore, if there is no shivering, the total body oxygen consumption curve is a fair index of the cerebral metabolic rate (Fig. 5).

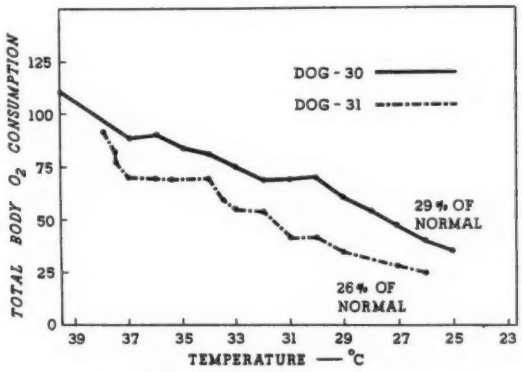


FIG. 4. Total body O_2 consumption.

b) *Cerebral Metabolic Rate.* From the A-V oxygen differences the cerebral metabolic rate was calculated (Fig. 5). The metabolic rate was expressed as the number of cc. of oxygen extracted by the brain per min. The A-V oxygen difference in volume per cent represents the number of cc. extracted by the brain per 100 cc. of blood. Therefore, the oxygen utilized from 1 cc. of blood is equal to this A-V oxygen difference divided by 100. If the cerebral blood flow at this time was Y cc. per min., then the cerebral metabolic rate would be Y $\times$ A-V oxygen difference divided by 100. Since the rate of blood flow was known for all the A-V oxygen differences, the cerebral metabolic rate could be calculated for various temperatures. The blood flow at 25°C. was usually a few cc. slower than that at 39°C., so that the reduction in cerebral metabolic rate was usually slightly more striking than that of the A-V oxygen differences. From Fig. 5 it will be seen that at 25°C. there is a reduction in cerebral metabolic rate which lies somewhere between 35 and 23 per cent of normal.

Elliott[11] stated that the temperature coefficient for each 10°C. change in temperature, Q_{10}, for rat brain respiration between 10° and 40°C. is 2.13. Since this Q_{10} is a normal value for chemical reactions in general it seems appropriate to use it to calculate the expected reduction in cerebral metabolic rate in these dogs. The reduction from 38 to 25°C. equals a drop of 13°C. and would be equivalent to a reduction in the cerebral metabolic rate to 1/2.77 or 36 per cent of the level at 38°C. It is interesting that this theoretically derived reduction in cerebral metabolic rate correlates fairly well with the reduction actually measured in the above dogs.

2) *Survival Studies.* According to our determinations the cerebral metabolic rate at 25°C. is reduced to about 25 per cent of normal. This should mean

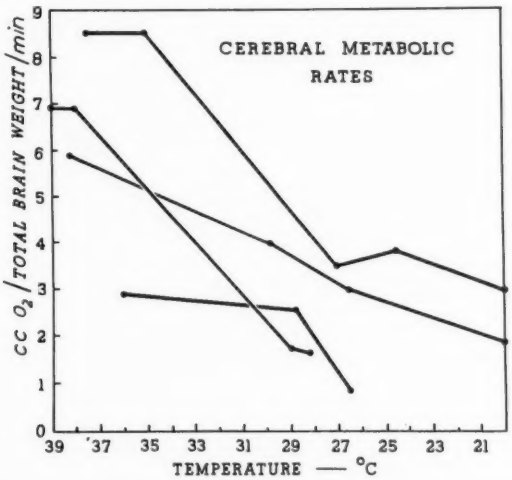


FIG. 5. As the temperature decreases, the cerebral metabolic rate is reduced. At 25° the cerebral metabolic rate varied between 35 and 23 per cent of normal values.

that the hypothermic animal at 25°C. would withstand anoxia for about four times as long as the normothermic animal. To test this hypothesis 8 animals when hypothermic at 25°C. were ventilated with 100 per cent nitrogen for 15 to 30 min. and the time required for electrocardiographic and electroencephalographic changes indicative of anoxia was noted.

In order to judge the length of such ventilation the animal would safely withstand, we observed the electrocardiogram and when marked changes indicative of anoxia and impending myocardial failure developed, the experiment was terminated by allowing the animal to breathe room air (Fig. 6).

The changes that usually occurred were lengthening of the PR and QT interval, elevation of the ST segment and high T-waves. As these changes progressed they were usually accompanied by an increasing bradycardia.

The changes appeared anywhere between 5 and 10 min. but did not become severe nor was there any fall in blood pressure, indicating myocardial failure, until at least 15 min. had elapsed. Some animals went as long as 30 min. If this anoxia was prolonged beyond the tolerance, death occurred as a result of cardiac arrest or ventricular fibrillation. When ventricular fibrillation occurred, it was a terminal phenomenon which usually commenced after

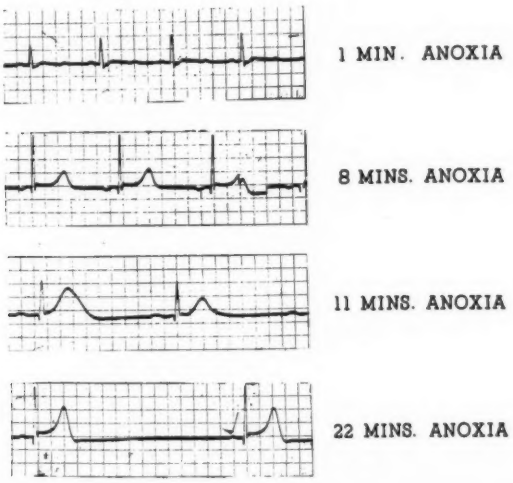


FIG. 6. Progressive changes in cardiogram during anoxia (breathing 100 per cent nitrogen) at 25° C.

normal ventricular contractions had ceased. The electrocardiographic changes which occurred at 5 min. in the hypothermic animals appeared within 1 min. in the normothermic animal. Of the 8 animals undergoing this test only 1 showed signs of clinical neurological deficit but this animal had sustained a severe loss of blood (over half of his blood volume) which may have prejudiced his recovery (Table 2).

TABLE 2

Survival

Dog	Temp.	Trachea Clamped	100% Nitrogen	Survival
1	24	30′	23′	Yes
2	23.6	40′	not done	Yes
3	24	—	22′	Yes
4	23.6	—	16′	Yes
5	25	—	17′	Yes
6	24	—	17′	Yes
7	24.5	—	17′	Yes
8	25	—	16′	Yes

3) *Electroencephalogram.* Scott *et al.*[24] and Chatfield *et al.*[7] have shown the depressant effect of hypothermia on the brain waves. Scott showed that in monkeys electrical silence occurred at 22°C. The brain waves of the dog at 25°C. are much reduced in amplitude and slow waves become more prominent. Since the brain waves are a sensitive test of cerebral dysfunction. it was felt that they would be a reliable and early indicator of cerebral anoxia. The electroencephalographic changes with anoxia are increase in

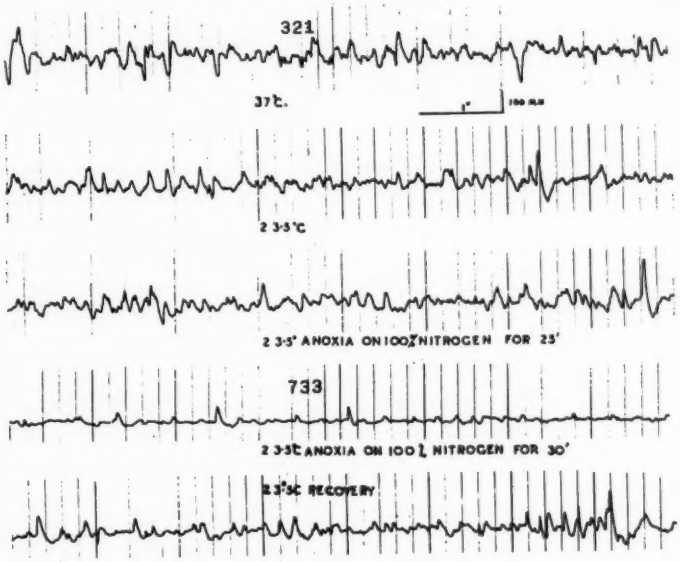


FIG. 7. EEG during hypothermia and anoxia.

number of slow waves and reduction in amplitude which, if carried further, approach electrical silence (Fig. 7). These changes appeared much later than the electrocardiographic changes and usually not until the latter were becoming severe. It was the heart, therefore, that limited the experiment and not the brain. It is possible that hypothermia results in a much greater reduction in cerebral oxygen requirement than that of the dynamically contracting myocardium. Had it not been for fear of myocardial failure, perhaps some of the animals could have remained anoxic for even longer without evidence of cerebral damage. The neurosurgeon does not need to render the heart anoxic, so perhaps the length of time the brain may be excluded from circulation can be increased. The animal who developed a neurological deficit had gross electroencephalographic changes and was the only animal showing any evidence of pathological changes of anoxia. The electroencephalogram, therefore, may be used to preclude carrying the period of anoxia too far.

4) *Pathology.* The brains of 5 of these animals were sectioned 6 months later and there was no specific evidence of anoxia in these specimens. In one brain, in the lateral thalamic area, there was a small region of decreased number of nerve cells with microglial and astrocytic reaction. In another brain, sections of the cortex showed an occasional patchy area of cellular loss with increased number of microglial cells. These changes were subtle and were not definitely abnormal. One could not be certain of the significance of these findings but there certainly were no typical findings of anoxia. This tends to support further the hypothesis that the cerebral tissues are protected by hypothermia from the adverse effects of anoxia.

5) *Further Data Indicating Little If Any Cerebral Hypoxia Or Anoxia Occurred.* It seems necessary to prove that the reductions in A-V oxygen differences were not caused by a shift in the oxygen dissociation curve but by a reduction in the oxygen requirement by the brain. It might be argued that this shift would prevent the cerebral tissue from taking up the oxygen it required and so render it hypoxic. The following facts support the theory that there was no hypoxia present:

a) Clinical and pathological evidence of cerebral damage did not occur from hypothermia alone.

b) Electroencephalographic changes were not severe and recovered on rewarming.

c) There was no increase in the A-V oxygen difference or total body oxygen consumption during rewarming.

d) The lactate:pyruvate ratio is an important indication of tissue anoxia. When tissues become anoxic, the lactate rises but the pyruvate stays constant or falls. Table 3 shows no significant rise during hypothermia and

TABLE 3

Lactate:pyruvate ratio

Temp.	Case 28			LP Ratio 33 Peripheral			Case 30		
	AL	AP	Ratio	AL	AP	Ratio	AL	AP	Ratio
39°C.	6.0	1.6	3.8				19.5	2.1	9.3
36°C.				18.2	2.4	7.6			
30°C.	4.4	1.1	4.0	27.2	2.9	9.4	20.0	1.6	12.5
25°C.	8.5	1.6	5.3	30.2	2.9	10.4	17.9	1.2	14.9
25°C. and anoxia 25 min.	42.2	2.1	20.0				48.8	1.6	30.4
							59.9	1.0	59.9
25°C. and anoxia 26 min.	51.0	1.1	46.3						
Post anoxia							56.0	2.4	23.3

AL=arterial serum lactate.
AP=arterial serum pyruvate.

hence the brain must be able to extract oxygen during hypothermia. However, at the end of 25 min. in an atmosphere of 100 per cent nitrogen the cerebral tissues become anoxic and by 26 min. the change in the lactate: pyruvate ratio is marked (Table 3). It, therefore, appears that the hypothermic brain is metabolizing oxygen and that the reduction in A-V oxygen differences during hypothermia is not caused by the change in the oxygen dissociation curve but rather by a decreased metabolic demand on the part of the brain.

SUMMARY

1) Preliminary studies of various types of extracorporeal circulation are presented. These procedures proved to be too time-consuming and technically too difficult to be of practical use.

2) All animals, except one, in which local cerebral hypothermia was tried, died of ventricular fibrillation, which appeared to have been precipitated by the creation of a myocardial temperature differential in the right heart.

3) An experimental method is presented for studying the metabolism of the cold brain.

4) The cerebral metabolic rate in hypothermia (25°C.) varied from 23 to 35 per cent of control values.

5) Total body oxygen consumptions were reduced and paralleled the reduction in the cerebral metabolic rate in the absence of gross clinical shivering.

6) Of 15 dogs cooled to 25°C. or lower, none developed ventricular fibrillation above 25°C. Below 25°C. 3 died of fibrillation.

7) Preliminary studies indicate that the percentage reduction in cerebral metabolic rate is a reliable index which can be used to calculate the time that the blood supply may be safely arrested. The brain waves and the cardiogram are also reliable guides in predicting the tolerance to anoxia.

8) Eight dogs at 23.6° to 25°C. survived 15 minutes of anoxia (ventilated with 100 per cent nitrogen) and only 1 showed neurological deficit.

9) Pathological examination of those surviving without clinical deficit revealed no signs of anoxia.

This work was supported by an Institutional Grant of the American Cancer Society to the Massachusetts General Hospital, by an anonymous donor to Dr. James C. White, and by the Neuro-Research Foundation.

We should like to thank Dr. E. P. Richardson and Dr. Bernard Stone of the Pathology Department of the Massachusetts General Hospital for their detailed examination of the pathological specimens, Miss J. Robinson for the histological preparation of slides, and Miss Wishart of the Art Department, University of Toronto, for diagrams and graphs.

REFERENCES

1. Barker, S. B., and Summerson, W. H. The colorimetric determination of lactic acid in biological material. *J. biol. Chem.*, 1941, *138:* 535–554.
2. Bigelow, W. G., Callaghan, J. C., and Hopps, J. A. General hypothermia for experimental intra-

cardiac surgery. The use of electrophrenic respirations, an artificial pacemaker for cardiac standstill, and radio-frequency rewarming in general hypothermia. *Ann. Surg.*, 1950, *132:* 531–537.

3. Bigelow, W. G., Lindsay, W. K., and Greenwood, W. F. Hypothermia. Its possible role in cardiac surgery. An investigation of factors governing survival in dogs at low body temperatures. *Ann. Surg.*, 1950, *132:* 849–866.
4. Bigelow, W. G., Lindsay, W. K., Harrison, R. C., Gordon, R. A., and Greenwood, W. F. Oxygen transport and utilization in dogs at low body temperatures. *Amer. J. Physiol.*, 1950, *160:* 125–137.
5. Brown, E. B., Jr., and Miller, F. Ventricular fibrillation following a rapid fall in alveolar carbon dioxide concentration. *Amer. J. Physiol.*, 1952, *169:* 56–60.
6. Campbell, G. S., Haddy, F. J., and Brown, E. B., Jr. Vagal inhibition of the dog heart at different blood pH levels. *Fed. Proc.*, 1953, *12:* 23.
7. Chatfield, P. O., Lyman, C. P., and Purpura, D. P. The effects of temperature on the spontaneous and induced electrical activity in the cerebral cortex of the golden hamster. *Electroenceph. clin. Neurophysiol.*, 1951, *3:* 225–230.
8. Clark, G. H. The influence of increase of temperature upon the inhibitory mechanism of the heart of the frog. *J. Physiol.*, 1912, *44:* 169–175.
9. Cramer, F. B., Jr., and Winnick, T. Amino acid nitrogen of normal human plasma. *J. biol. Chem.*, 1943, *150:* 259–260.
10. Delorme, E. J. Experimental cooling of the blood-stream. *Lancet*, 1952, *2:* 914–915.
11. Elliott, K. A. C. Brain tissue respiration and glycolysis. In: *The biology of mental health and disease.* Milbank Memorial Fund. New York: P. B. Hoeber, Inc., 1950, xxv, 654 pp. (see pp. 54–70).
12. Evelyn, K. A. A stabilized photoelectric colorimeter with light filters. *J. biol. Chem.*, 1936, *115:* 63–75.
13. Friedemann, T. E., and Haugen, G. E. Pyruvic acid. II. The determination of keto acids in blood and urine. *J. biol. Chem.*, 1943, *147:* 415–442.
14. Hegnauer, A. H., Shriber, W. J., and Haterius, H. O. Cardiovascular response of the dog to immersion hypothermia. *Amer. J. Physiol.*, 1950, *161:* 455–465.
15. Hoff, H. E., and Stansfield, H. Ventricular fibrillation induced by cold. *Amer. Heart J.*, 1949, *38:* 193–204.
16. Jensen, J. M., and Parkins, W. M. Brain tolerance to differential hypothermia and circulatory occlusion. *Fed. Proc.*, 1954, *13:* 75.
17. Lewis, F. J., and Taufic, M. Closure of atrial septal defects with the aid of hypothermia; experimental accomplishments and the report of one successful case. *Surgery*, 1953, *33:* 52–59.
18. Markwalder, J., and Starling, E. H. On the constancy of the systolic output under varying conditions. *J. Physiol.*, 1914, *48:* 348–356.
19. Miller, F. A., Brown, E. B., Buckley, J. J., Van Bergen, F. H., and Varco, R. L. Respiratory acidosis: its relationship to cardiac function and other physiologic mechanisms. *Surgery*, 1952, *32:* 171–183.
20. Nelson, N. A photometric adaptation of the Somogyi method for the determination of glucose. *J. biol. Chem.*, 1944, *153:* 375–380.
21. Patterson, S. W., Piper, H., and Starling, E. H. The regulation of the heart beat. *J. Physiol.*, 1914, *48:* 465–513.
22. Patterson, S. W., and Starling, E. H. On the mechanical factors which determine the output of the ventricles. *J. Physiol.*, 1914, *48:* 357–379.
23. Penrod, K. E. Cardiac oxygenation during severe hypothermia in dog. *Amer. J. Physiol.*, 1951, *164:* 79–85.
24. Scott, J. W., McQueen, D., and Callaghan, J. C. The effect of lowered body temperature on the EEG. *Electroenceph. clin. Neurophysiol.*, 1953, *5:* 465.
25. Swan, H., Maresh, G., Johnson, M. E., and Warner, G. The experimental creation and closure of auricular septal defects. *J. thorac. Surg.*, 1950, *20:* 542–551.
26. Van Slyke, D. D., and Neill, J. M. The determination of gases in blood and other solutions by vacuum extraction and manometric measurement. I. *J. biol. Chem.*, 1924, *61:* 532–573.
27. Wégria, R., Frank, C. W., Misrahy, G. A., Sioussat, R. S., Sommer, L. S., and McCormack, G. H., Jr. Effect of auricular fibrillation on cardiac output, coronary blood flow and mean arterial blood pressure. *Amer. J. Physiol.*, 1950, *163:* 135–140.

THE USE OF HYPOTHERMIA IN SURGICAL TREATMENT OF CEREBRAL VASCULAR LESIONS

A PRELIMINARY REPORT

W. M. LOUGHEED, M.D.,* W. H. SWEET, M.D., J. C. WHITE, M.D., AND W. R. BREWSTER, M.D.

Neurosurgical Service, Massachusetts General Hospital, Boston, Massachusetts

(Received for publication January 31, 1955)

THE present-day approach to some of the cerebral vascular lesions is limited and hazardous because the neurosurgeon cannot approach the lesion with sufficient control of the circulation.

We believe that in certain carefully picked cases hypothermia may afford the neurosurgeon the necessary protection to enable him to deal with the lesion definitively. A mortality of roughly 50 per cent is to be expected if the aneurysm ruptures during the intracranial exposure. Hypothermia is not without risk and the calculated risk taken must be balanced by the risk offered to the patient by other avenues of approach.

In animals, we have found that at 25°C. the cerebral metabolic rate is reduced to between 23 and 35 per cent of normal and that these animals will survive ventilation with 100 per cent nitrogen for as long as 15 to 22 minutes without physiological or histological evidence of cerebral damage. Hence it seemed probable that human cerebral cells at 25°C. would survive arterial occlusion 3 or 4 times as long as they do at normal body temperatures.

In December, 1953, there were 2 patients on the Neurosurgical Service of the Massachusetts General Hospital, who appeared to be excellent candidates for a trial with hypothermia. The results of its use are reported below.

METHOD

The patients were anaesthetized with thiopental and intubated in the usual fashion. The jugular vein on the right side was cannulated with two polyethylene tubes. The end of one tube was inserted into the right atrium and the end of the other into the jugular bulb. The tube leading to the right atrium was used for continuous venous pressure recordings and for blood samples. The other tube was used for blood samples.

In the first patient, the carotid artery was dissected and a loop was passed around the internal carotid in order to control the blood flow to the right side of the brain. In the second patient, both carotid arteries and vertebral arteries were dissected and loops were placed around all four. A Cournand needle was placed in the radial artery for continuous recording of

* Present address: Toronto General Hospital, Toronto, Ontario.

the blood pressure. Electroencephalographic and cardiographic leads were connected with the patient and a continuous recording of the total body oxygen consumption was taken using a Benedict-Roth spirometer. A rectal thermocouple and a centigrade thermometer were inserted into the rectum in order to obtain continuous recordings of the rectal temperature (Figs. 1 and 2).

Below is a list of the data recovered from each patient:

1) Rectal temperature
2) Continuous intra-arterial pressures
3) Electroencephalogram
4) Electrocardiogram
5) Arterial blood pH and CO_2 content
6) Right atrial venous pressure
7) Total body oxygen consumptions
8) Arterial serum lactate
9) Arterial serum pyruvate
10) Arterial O_2 content in vol. %
11) Jugular venous serum lactate
12) Jugular venous serum pyruvate
13) Jugular venous O_2 content } in vol. %
14) Right atrial venous O_2 content }
15) Arterial serum K
16) Arterial serum Na
17) Arterial serum Cl
18) Arterial hemoglobin
19) Arterial hematocrit
20) Arterial serum citrate
21) Arterial serum Ca
22) Arterial serum total protein

We should like to point out that not all these determinations are necessary in order to control a hypothermic patient, but we feel that this type of data would be ideal in order to give us a more thorough understanding of the physiological changes occurring. The first six, however, are necessary. These basic data were obtained at normothermic temperatures and following the taking of blood samples the patient was placed in an ice-water bath.

In the first case, an ordinary bath-tub was used, which was in the anaesthetic room, and this was found to be unsatisfactory because transportation of the patient to the operating table necessitated disconnecting and reconnecting all the recording devices.

For the second patient, a special monel metal trough was devised which fits on to the operating room table,* and into this can be circulated ice water or warm water when so desired. The patient's temperature was lowered by immersing his body in ice water as described above and the listed blood samples were taken and data recorded as his temperature dropped. When the

* Made by W. M. B. Berry Co., 117 Causeway St., Boston 13, Mass.

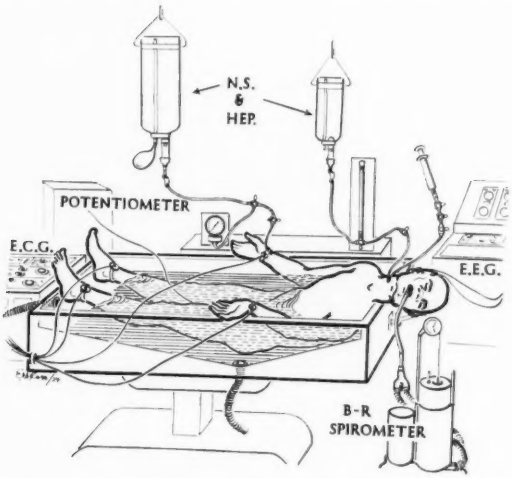


FIG. 1. Showing patient in the hypothermic bath with the right radial artery cannulated for blood pressure measurements and the jugular vein connected to a manometer. (N.S. & HEP = Normal saline and heparin.)

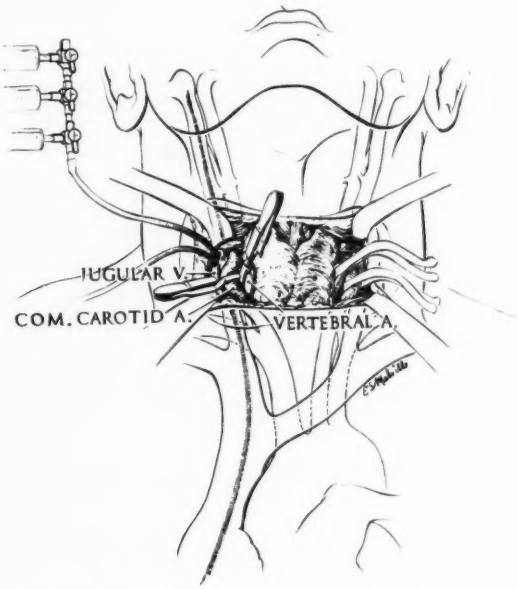


FIG. 2. Carotid and vertebral arteries are isolated. Polyethylene tubing enters the right jugular vein going to the right heart and right jugular bulb.

temperature was reduced to a satisfactory level, the intracranial portion of the operation was commenced. When the surgeon desired an avascular field, both carotid arteries were occluded in the first patient, and in the second patient both carotid and both vertebral arteries were occluded and the times of their occlusion noted.

Following the completion of the operative procedure, but before the bone flap was replaced, the patient was rewarmed by circulating water at 42°C. through the bath. In the first case, the rewarming was done by a rubber air mattress, through which hot water was circulated. This was far from satisfactory. Unfortunately, the circulation of the hot water in the air mattress was not good at the point of inflow and the water was hotter than at the point where it was flowing from the mattress. At the point of inflow the patient sustained a second-degree burn, which was approximately 6×4 inches in area. The second patient also sustained a small burn, the size of a fifty-cent piece, over the lateral malleolus. This was because of the fact that the temperature of the inflowing water during rewarming fluctuated and at one point became too hot. These points, however, are technical errors and can easily be overcome by the inclusion of a thermostat in the inlet.

CASE REPORTS

Case 1. W. M., a 45-year-old male, was suffering from a recurrent glioblastoma of his right cerebral hemisphere. He had a left hemiplegia and was suffering from severe right-sided headaches.

Following his admission to the ward he progressively deteriorated in his level of consciousness because of increased intracranial pressure. A hemispherectomy was decided upon as it would perhaps give him 6 to 8 months of useful existence. One of us, J.C.W., felt that it would be difficult to isolate the middle cerebral and posterior cerebral arteries as in the ordinary hemispherectomy because they would be involved in tumour tissue, and that bleeding would be a problem in this approach. Although admittedly this procedure could have been carried out with the aid of hypotension, it seemed to us that this was the type of case in which we should first use hypothermia prior to proceeding to patients who had more to gain.

The patient was anaesthetized with thiopental and intubated in the usual fashion. He was prepared for the hypothermia as described under "Method," and was then placed in an ice-water bath and his temperature dropped from 35.5°C. to 32°C. in 30 min. At this point the ice water was removed and the patient was transported to the operating table. During this time a 14-min. period elapsed and his temperature, when measured again, had dropped to 29.4°C. At this juncture he had a grossly abnormal electrocardiogram (Fig. 3, 11:31 a.m.). This alarming arrhythmia, which was called in retrospect an auricular flutter, was treated by hyperventilation and rapid withdrawal of 50 cc. of blood from the catheter leading to his right atrium. The cardiogram promptly reverted to sinus rhythm and that abnormal rhythm did not recur. He continued to cool very slowly from this point on and eventually 4 hours later reached 26°C., where he stabilized. At 26°C. auricular fibrillation occurred and continued until he was rewarmed.

During the 4-hour period when his temperature was slowly dropping from 29 to 26°C., occlusion of carotid arteries was carried out to aid removal by J. C. W. of the

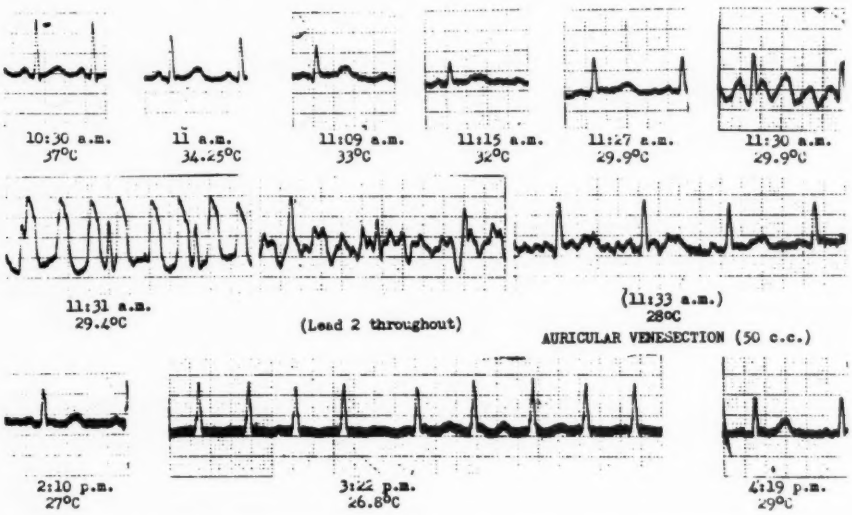


FIG. 3. *Case 1.* Demonstrating changes in cardiac rhythm during hypothermia.

right hemisphere. The right carotid artery was occluded for 31 min. and during this period there were three 5-min. periods of occlusion of the left common carotid. There was a final 63-min. period of occlusion of the right common carotid and during this time the left common carotid was again occluded for three 5-min. periods. The time intervals and total times of occlusion are shown in Table 1 (Case 1). It was felt that bilateral carotid occlusion would suffice to reduce the blood supply, so that dissection could be carried out in a bloodless fashion. This, however, proved to be fallacious. There was quite a bit of bleeding, which was taken to be coming from the vertebral arteries.

We, therefore, learned in this case that it was not sufficient to occlude solely the two carotid arteries but it would be necessary, if a bloodless field was desired, to occlude the vertebral arteries also. The hemisphere was dissected without difficulty and the patient was rewarmed to 35°C. prior to replacing the bone flap. This rewarming was considered necessary in order to be certain that adequate hemostasis had been achieved.

The patient's postoperative course was uneventful. He was alert the day following operation and asked to smoke a cigarette on the evening of his first postoperative day. He was mentally alert, orientated and fully conscious and showed no signs of having suffered cerebral anoxia. He was out of bed on his 50th postoperative day.

His postoperative course demonstrated only one disturbing feature. This was the development of a tachycardia of the order of 150 beats per min. Electrocardiograms taken serially during his postoperative recovery showed inversion of the T-waves in most leads. Although these may have been indicative of diffuse myocardial damage, the exact etiological mechanism was not clear. However, in the course of time (5 to 6 days) the pattern of his electrocardiogram reverted to normal and the T-wave changes disappeared. It was believed that this change probably represented a metabolic change rather than structural damage to the myocardium.

Case 2. R.C., a 17-year-old white male, weighing 135 pounds, was suffering from a large arteriovenous malformation, which lay between the two cerebral hemispheres, totally below the corpus callosum and supramesencephalic (Fig. 4). It extended down between the two thalami. Previously, on June 11, 1951, both anterior cerebral arteries had been clipped as they approached the lesion. Following this procedure hemorrhages did not recur until January 1952. After several more bleedings the right posterior cerebral and posterior communicating arteries were clipped on March 5, 1952. A succession of hemorrhages began again on Nov. 18, 1953, and bilateral carotid arteriograms now showed a lesion of undiminished size fed by new

TABLE 1

Times of occlusion

Case	Temp.	Interval Between Occlusion	Time Occluded			
			Carotid Arteries		Vertebrals	
			R Min.	L 5 Min. Periods	R	L
1	27		31	3	0	0
	26.8	38	41	3	0	0
	26.0	5	63	3	0	0
Total time of occl.			135 min.	45 min.	0	0
			5′	5′	5′	5′
2	25.8	2	3′45″	3′45″	3′45″	3′45″
		8	3′30″	3′30″	3′30″	3′40″
		55	4′30″	4′30″	4′30″	4′30″
		16	14′25″	14′25″	14′25″	14′25″
		32	5′45″	5′45″	5′45″	5′45″
		7	10′10″	10′10″	10′10″	10′10″
Total time of occl.			47′05″	47′05″	47′05″	47′15″

collaterals from the left anterior and right middle cerebral arteries. He was completely bedridden, lying in opisthotonos and continually crying out with pain from recurrent hemorrhages. It was felt that something definitive was necessary for this boy and that it perhaps would be feasible to attack the aneurysm with the aid of hypothermia.

He was anaesthetized in the usual fashion and then placed in the monel metal bath, which was attached to the operating room table. He was placed in the desired position for a craniotomy and with his head in the head-rest, which was attached to the monel metal bath. Ice-cold water was then irrigated through the bath and the patient's temperature fell from 37 to 31.5°C. in 43 min. At this point the ice water was removed and he continued to cool during the next 30 min. to 26.7°C. Fifty-five min. later his temperature was stable at 24°C.

This patient's course throughout hypothermia was much more stable than that of our first case, in which gross shivering occurred. In the second patient, there was no gross shivering, although there was an indication at times, through interference observed on the electrocardiographic tracing, of occult shivering. At 26°C. auricular

fibrillation occurred and this remained until rewarming was commenced (Fig. 5).

The patient's rectal temperature varied between 26°C. and 24°C. for 6 hrs. and it was during this time that carotid and vertebral occlusion was practised. Both carotid arteries and vertebral arteries were occluded for short periods of time in order to allow surgery to be carried out intracranially. When all four vessels were occluded, one of us, W.H.S., occluded the branches of the arteriovenous aneurysm

FIG. 4. *Case 2.* Dr. Samuel Brendler's right vertebral arteriogram on Feb. 6, 1952, showing arteriovenous malformation in region of great vein of Galen and straight sinus. The silver clips are on the anterior cerebral vessels just caudal to the origin therefrom of the branches passing to the paracentral lobules. They were applied at the first operation on June 11, 1951.

with silver clips and attempted to dissect around the periphery of this anomaly. The longest time that all four vessels were occluded was 14 min. and 25 sec. The sum total of all such periods of occlusion was 47 min. and 15 sec. This was carried out over a period of 120 min. (Table 1).

It was possible, using this method, to clip most of the vessels of the aneurysm. The cerebral hemisphere showed no visible evidence during the periods of occlusion of anoxia or oedema. Prior to closing, rewarming was started and 1 hr. and 15 min. later the patient's temperature was 34°C. At this point he was removed from the water bath and allowed to rewarm slowly. In 2 hrs. his temperature had reached 37.5°C.

This patient's postoperative course was uneventful for the first 5 days. He was alert and talking on the morning of his first postoperative day. He had a partial right hemiplegia, which was attributed to the retraction on the left cerebral hemisphere and occlusion of major draining veins during the procedure. On his 4th postoperative day he was making plans with his mother for his postponed Thanksgiving dinner, but the next morning he was in coma with irregular gasping respirations and within a short time he died.

Autopsy showed the right vertebral artery to be thrombosed from the site of occlusion in the neck up to its junction with the basilar artery. We assume that when the propagating thrombus in the right vertebral artery reached the level of the brain stem, the return collateral supply via the other vertebral and the basilar arteries was stopped. Hence the rather abrupt demise with respiratory arrest. There was an area of softening in the mid-brain, which was presumably caused by an embolus from the thrombosed vertebral artery. This thrombosis was caused by trauma produced by the occluding bulldog clamp. There were several factors, we

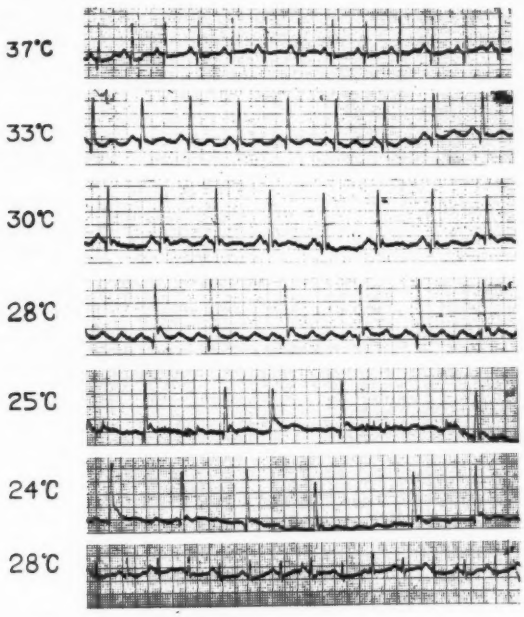


FIG. 5. *Case 2.* Electrocardiogram during hypothermia.

believe, that culminated in this trauma. First of all, the neck was in such a position during the operation that it was very difficult to visualize the vertebral arteries when applying the occluding clamps. Secondly, clamps were chosen that were particularly stiff in order to assure that all blood supply would be occluded. We think in the future this complication could be easily avoided by using rubber-shod Poppen clamps. Sections of the cerebral hemispheres did not indicate any pathology attributable to the periods of circulatory arrest.

In this case also in the early postoperative recovery period a tachycardia developed, as in Case 1. This, however, was not severe; the T-wave changes were not as marked, and all of these changes had returned to normal prior to his death.

At autopsy, the arteriovenous malformation appeared to have been completely occluded by the surgical attack.

PRESENTATION OF PERTINENT DATA

1) *Total Body Oxygen Consumption.* This figure for the first patient at 37°C. was 167.2 cc./min. at 0°C. and 760 mm. Hg. It rose to 249 cc. during

shivering and eventually dropped to 110 cc. at 26°C. This represented a 35 per cent reduction in the basal metabolic rate. The second patient started with a total body oxygen consumption of 190 cc. at 37.5°C. which progressively fell linearly to 99 cc. at 24°C. This represented a 52 per cent reduction (Fig. 6). We do not think that either of these oxygen consumptions is at all representative of the true cerebral metabolic rate. There was present in both of these patients subclinical shivering, which could be detected by interference present in the electrocardiogram. Obviously, this shivering would in-

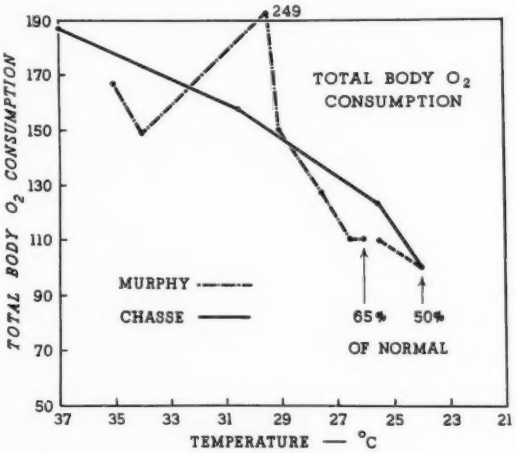


FIG. 6. The dotted line represents the first patient and the solid line the second patient.

crease the total body oxygen consumption whereas it would have no bearing upon the cerebral metabolic rate. This statement is further reinforced by the fact that the second patient sustained a period of total cerebral circulatory arrest which was at least three times the length he would have survived at normal temperature without neurological sequelae.

2) *Cerebral Arteriovenous Oxygen Differences* (Fig. 7). In Case 2 the initial cerebral A-V oxygen difference was very low because of the fistula. Following the completion of surgery, this A-V oxygen difference rose by virtue of a drop in the venous oxygen content which ensued upon occlusion of the A-V fistula. However there was no significant change in the cerebral arteriovenous oxygen difference during cooling. In Case 1, a progressive fall in the cerebral A-V oxygen difference occurred with lowering of the body temperature at a time when the systemic A-V oxygen difference tended to increase and when the cardiac output was decreased. Although not conclusive in themselves, as cerebral blood flow was not measured, these reduced cerebral A-V oxygen differences are in keeping with similar reported findings in our dogs in which a reduction in the cerebral metabolic rate during hypothermia was measured.

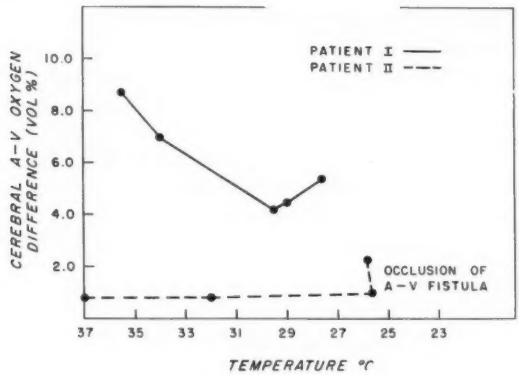


FIG. 7. Cerebral arteriovenous oxygen differences.

We attempted to measure cerebral blood flow in Case 2 by the N_2O method, but the arteriovenous fistula made interpretation of the results impossible.

3) *The Electroencephalogram.* When the patient becomes hypothermic, the electroencephalogram develops a greater proportion of slow waves but the voltage remains about the same. In monkeys and dogs that have been

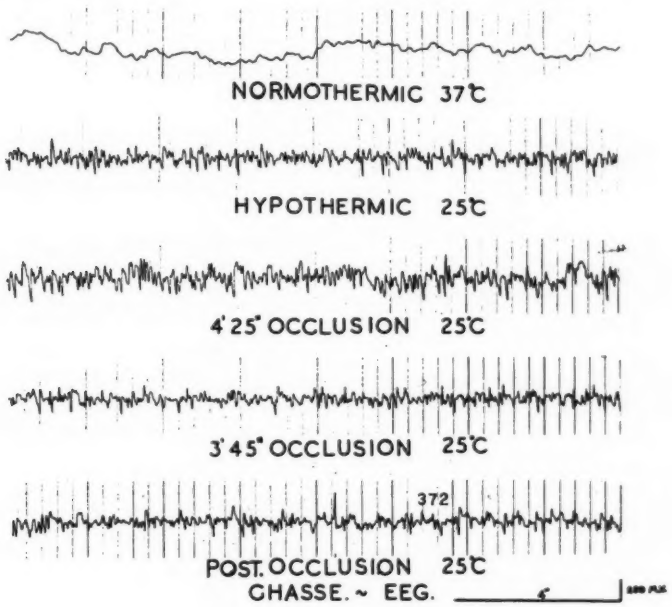


FIG. 8. *Case 2.* Electroencephalogram.

rendered anoxic, slow waves are first to appear. These are followed by a gradual diminution in amplitude of the wave and, if anoxia continues, electrical silence will ensue. Neither of the patients showed evidence of change of their waves during hypothermia and Fig. 8 depicts a normothermic and subsequently hypothermic brain with complete cerebral circulatory arrest. It will be noted in this figure that during the periods of 4 min. and 25 sec. and 3 min. and 45 sec. in which there was circulatory arrest in this hypothermic brain it did not show any electroencephalographic changes characteristic of anoxia. Fig. 9 shows the electroencephalogram of a dog at 25°C. breathing 100 per cent nitrogen for 30 min. Here the brain waves are approaching electrical silence. At 25 min., however, the brain waves appeared normal.[2]

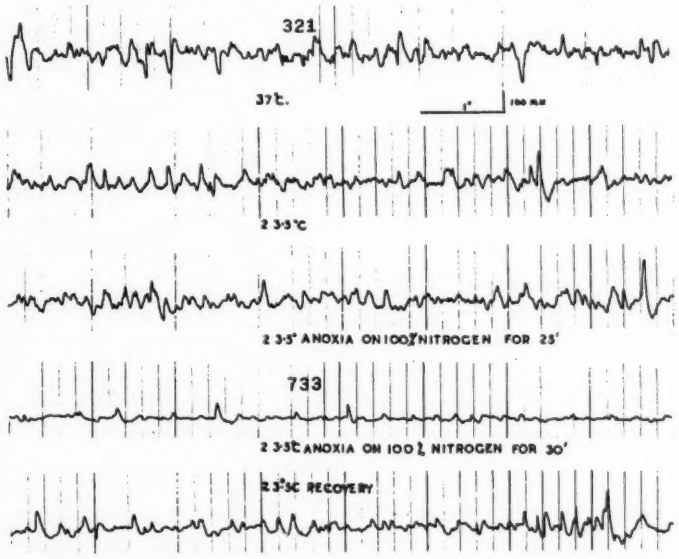


FIG. 9. Electroencephalogram of a dog under hypothermia with anoxia for 30 minutes.

The electroencephalogram is, therefore, a rough guide to the status of the cerebral tissues during circulatory arrest in hypothermia.

4) *Cardiovascular Effects of Hypothermia.* (a) *Electrical Changes.* In both patients a regular sinus rhythm was maintained until a rectal temperature of 29°C. was reached. In Case 1, a brief episode of presumed auricular flutter occurred at 29.4°C. and shortly disappeared to be followed again by a regular sinus rhythm. This patient then showed auricular fibrillation at 26.8°C. In Case 2, this arrhythmia occurred at 29°C. It persisted in both patients throughout the hypothermic period. Patients 1 and 2 reverted to a regular sinus rhythm during rewarming at 29°C. and 28°C. respectively (Fig. 3 and Fig. 5).

The heart rate of both patients decreased below control values during cooling as shown in Fig. 10. The lowest rates observed were 50/min. and 52/min. in Cases 1 and 2 respectively. A sinus tachycardia, heart rate 150/min. with T-wave inversion in all leads occurred postoperatively in both patients. The heart rate returned to normal and T-wave changes disappeared in both patients a few days postoperatively.

(b) *Hemodynamic Effects.* The mean radial blood pressure remained at or above control values in both patients during the cooling period. Both patients showed a rise in the mean arterial pressure during the period of cooling

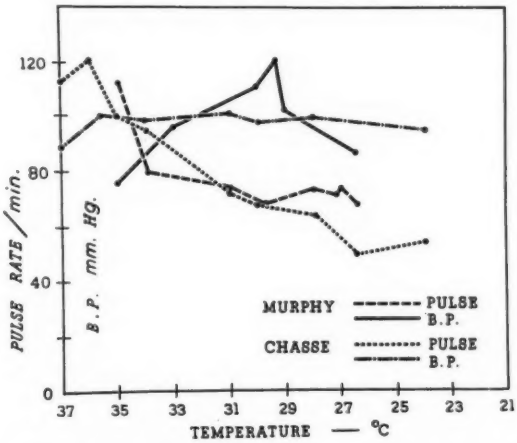


FIG. 10. Showing decrease in heart rate in both patients during cooling.

in the ice bath. This is in agreement with the well known effects of the cold stimulus. At rectal temperatures of 26.8°C. and 25.5°C., the mean radial arterial pressures of both patients closely approximated those observed in their normothermic anaesthetized control state. Hypotension was not found to be a consequence of this type of body cooling at rectal temperatures above 25°C. (Fig. 10). However, the peripheral pulses could not be obtained when the patient was hypothermic even though we were able to palpate the carotid arteries through the wound in the neck.

Valid cardiac output studies were not done because of the reported high incidence of ventricular fibrillation[1] during catheterization of the cooled dog heart. Central venous pressures were recorded through a catheter inserted to the right auricular level. These fell somewhat in Case 2 but there was no significant change in Case 1 during the cooled period.

5) *Blood Chemistry.* Studies of the *serum pH* and *total CO_2 content* (volume per cent) were done and the pressure of CO_2 in the serum, pCO_2, was calculated from the Singers-Hastings nomogram. The serum pH was determined by the colorimetric technique of Hastings and Sendroy at a bath tempera-

ture identical to the patient's body temperature rather than the usual 88°C. bath temperature. No striking changes occurred. Both patients ventilated spontaneously throughout the cooling procedures; and the absence of major hyperventilating manoeuvers by the anaesthesiologist contributed to the stability of the pH. Patient 1 showed no significant change in his serum CO_2 tension while patient 2 showed a rise in the serum pCO_2 from a control value of 35 mm. Hg to 50 mm. Hg during the lowering of the body temperature. This latter tension of CO_2 remained constant throughout most of the procedure, returning to normal towards the end of the intracranial portion of the operation.

Determinations of the *serum sodium, potassium,* and *chloride concentrations* were done in both patients. In Case 1 there was a rise in serum potassium concentration of 0.8 meq/l. in the early portion of the cooling procedure during gross shivering. This returned to normal values at a temperature of 28°C. and remained normal throughout the rest of the procedure. There was no significant change in the serum potassium concentration in

TABLE 2

Case 1. Blood chemistry determinations

Sample	Time						
	10:18 A.M. Control	11:05 A.M.	12:05 P.M.	12:55 P.M.	2:02 P.M.	3:04 P.M.	4:22 P.M.
Rectal Temperature—°C.	35.5	34.0	29.5	29.0	27.6	26.8	27.0
Central Venous Pressure (cm. H_2O)	−4.5	−0.5	−5.0	−6.5	−5.5	−5.5	−4.5
Mean Radial Arterial Pressure (mm. Hg)	77	95	112	104	80	88	60
Heart Rate/min.	112	80	68	78	72	68	68
Oxygen Consumption cc./mm./S.T.P.	167.2	149.5	249.0	150.0	127.0	110.0	114.0
Arterial pH at Patient's Temperature	7.40	7.37	7.28	7.33	7.33	7.36	7.47
Total CO_2 Content Serum—Vol. %	25.8	26.9	22.3	20.4	20.0	21.0	—
Serum Lactate (Arterial) mg.%	11.5	9.8	48.9	56.3	56.8	44.1	75.0
Serum Lactate (Jugular Vein) mg.%	12.6	12.1	47.7	54.1	53.4	38.8	71.8
Serum Pyruvate (Arterial) mg.%	1.7	1.2	2.8	3.0	3.2	2.9	4.2
Serum Pyruvate (Jugular Vein) mg.%	1.4	1.3	2.8	2.9	3.2	2.9	4.2
Blood Sugar (Arterial) mg.%	118	124	161	198	252	—	360
Blood Sugar (Jugular Vein) mg.%	108	112	153	187	245	252	338
Oxygen Content (Arterial) Vol. %	18.3	18.6	20.2	17.5	17.8	17.6	15.7
Oxygen Content (Jugular Vein) Vol. %	9.6	11.6	16.0	—	13.3	12.2	5.6
Cerebral A-V O_2 Difference—Vol. %	8.7	7.0	4.2	—	4.5	5.4	10.0
Serum Potassium (Arterial) meq/l.	4.3	4.4	5.0	5.1	3.9	4.0	3.9
Serum Sodium (Arterial) meq/l.	137	130	130	128	130	128	122
Serum Chloride (Arterial) meq/l.	102	—	102	102	98	100	98
Hemoglobin (Arterial) gm.%	13.7	13.7	15.6	13.7	13.3	12.7	10.3
Hematocrit (Arterial) %	35	37	37	32	32	29	28
Serum Citrate (Arterial) mg.%	2.3	—	—	—	4.1	5.5	10.9
Serum Calcium (Arterial) mg.%	—	—	—	8.1	8.3	8.5	8.1
Serum Total Protein—gm.%	6.3	—	—	—	5.8	5.6	4.8
pCO_2 (Arterial) mm.Hg	40	44	45	37	37	36	—
Lactate: Pyruvate Ratio (Arterial)	6.8	8.2	17.4	18.8	17.7	15.2	17.8

Case 2 during the period of hypothermia, nor was there any significant change in the serum sodium or chloride concentrations in this patient. There was, however, a progressive fall in the serum sodium concentration of patient 1, in whom the presence of the "salt wasting syndrome" made pre- and postoperative electrolyte maintenance difficult.

For the determinations of *hemoglobin*, *hematocrit*, *citrate*, *calcium* and *total protein*, see Tables 2 and 3. The hemoglobin, hematocrit and serum protein remained constant in Case 2, but in Case 1 there was a progressive fall in all three of these parameters. This was because of the fact that the patient's blood loss during operation was not adequately replaced. The serum citrate rose quite markedly in both of these patients, and the serum calcium fell. We thought the explanation for this was that the citrate contained in the blood used for transfusion could not be detoxicated adequately by the hypothermic liver. For this reason we have used in subsequent cases the ion exchange resin technique of the Fenwal Corporation to decrease the coagulability of transfused blood.

Serum lactate and *pyruvate* and *blood sugar* were measured (Tables 2 and 3) in both arterial and jugular venous blood in Case 1. The figures were simi-

TABLE 3

Case 2. Blood chemistry determinations

Sample	Time					
	11:07 A.M. Control	11:35 A.M.	12:15 P.M.		2:06 P.M.	4:20 P.M.
Rectal Temperature—°C.	37	32	25.6	24.0	25.5	25.8
Central Venous Pressure (cm. H_2O)	−1.5	−3.5	−0.5	−2.5	−5.0	−8.0
Mean Radial Arterial Pressure (mm. Hg)	88	102	102	94	84	80
Heart Rate/min.	118	72	50	55	76	79
Oxygen Consumption cc./mm./S.T.P.	187.2	157	122	99	109	131
Arterial pH at Patient's Temperature	7.48	7.37	7.40	—	7.32	7.40
Total CO_2 Content Serum—Vol. %	27.2	30.4	30.4	—	27.0	27.2
Serum Lactate (Arterial) mg.%	8.7	11.2	8.9	—	10.3	25.3
Serum Pyruvate (Arterial) mg.%	2.2	1.9	2.1	—	2.7	3.2
Blood Sugar (Arterial) mg.%	120	142	170	—	189	243
Oxygen Content (Arterial) Vol. %	19.2	20.4	21.2	—	20.7	19.9
Cerebral Venous Oxygen Content—Vol. %	18.4	19.6	20.2	—	17.2	17.6
Cerebral A-V O_2 Difference—Vol. %	0.8	0.8	1.0	—	3.4	2.3
Serum Potassium (Arterial) meq/l.	3.8	3.2	3.2	—	3.6	3.9
Serum Sodium (Arterial) meq/l.	143	137	139	—	131	139
Serum Chloride (Arterial) meq/l.	98	96	98	—	100	100
Hemoglobin (Arterial) gm.%	15.1	15.1	15.1	—	14.7	15.1
Hematocrit (Arterial) %	34	38	40	—	34	34
Serum Calcium (Arterial) mg.%	9.2	—	—	—	—	7.7
Serum Citrate (Arterial) mg.%	2.1	—	—	—	—	16.3
Serum Total Protein—gm.%	6.2	—	—	—	—	6.3
pCO_2 (Arterial) mm. Hg	35.2	50	47	—	50	42
Lactate:Pyruvate Ratio (Arterial)	4.0	5.9	4.2	—	3.8	7.9

lar at the two sites of sampling, and in Case 2 only arterial specimens were obtained. The breakdown of glucose to lactic acid and the reduction of pyruvic acid to lactic acid occur readily under anaerobic conditions. But the further breakdown of lactic acid requires oxygen. Hence an increase in lactic acid concentration or in the lactate:pyruvate ratio is evidence of tissue hypoxia. The accepted upper limit for the normal ratio is 15:1, and this was exceeded in Case 1. However the gross shivering with production of an oxygen debt in the muscle could explain this effect, so that hypothermia alone may not have caused any tissue hypoxia. Indeed, in the second patient, who was carried at a lower temperature, but in whom no gross shivering was observed, the lactate:pyruvate ratio remained well within normal limits. We have considered the rise in serum pyruvate and blood sugar in both patients to represent metabolic sequelae of the reflex release of epinephrine by the sympathetic stimulation of cold and surgery.

6) *Level of Anaesthesia.* The sequence of events in Case 1 indicate the importance of close control of the depth of anaesthesia in the hypothermic patient. When gross shivering occurred in him, his total body oxygen consumption rose markedly and his lactate:pyruvate ratio exceeded the upper limits of normal. These changes pointed to oxygen deprivation in the tissues. A rise in serum potassium also occurred in the same period. Lightening of anaesthesia is evident not only from gross clinical shivering, but also in the occult or subclinical shivering to be noted on close inspection of both the electrocardiogram and the electroencephalogram. Presumably this should be at a minimum. Figures for the total body oxygen consumption may also be helpful since a linear fall in this parameter correlated with the fall in temperature appears to indicate the administration of sufficient anaesthetic agent.

On the other hand, it may be that cessation of respiration at a higher rectal centigrade temperature than the mid twenties, suggests that too much anaesthetic agent has been given. These two patients did not stop breathing at any time. When the hyperventilation technique of Swan and Zeavin[3] is used in order to avoid ventricular fibrillation of course the clue from spontaneous respiration is no longer available.

We were encouraged by the brilliant successes of Swan in operations on the heart in man under hypothermia to carry our own efforts from dog to man.

SUMMARY

1) The ability to occlude the circulation of the brain places a valuable tool in the hands of the neurosurgeon and if the procedure could be rendered sufficiently safe, the fields of aneurysmal surgery and other vascular neurosurgery could be extended.

2) Two patients have been rendered hypothermic for periods of 6 and 7 hours and rewarmed without incident.

It has been demonstrated that hypothermia protects the brain from

anoxia and will allow a total cerebral circulatory arrest for periods as long as 14 minutes and 25 seconds. The sum total period of occlusion for both carotid and vertebral arteries was 47 minutes and 15 seconds. This allowed a huge arteriovenous malformation to be dealt with adequately. The changes in the blood electrolytes, oxygen, lactate and pyruvate were discussed. The electrocardiographic and electroencephalographic tracings showed no evidence of anoxia occurring in the heart or brain during the periods of hypothermia or periods of circulatory arrest.

It is suggested that if this technique proves safe, it may be employed in the intracranial attack on aneurysms.

This work was supported by an Institutional Grant to the Massachusetts General Hospital by the American Cancer Society, by an anonymous donor to Dr. James C. White, and by the Neuro-Research Foundation.

REFERENCES

1. Hegnauer, A. H., Shriber, W. J., and Haterius, H. O. Cardiovascular response of the dog to immersion hypothermia. *Amer. J. Physiol.*, 1950, *161:* 455–465.
2. Lougheed, W. M., and Kahn, D. S. Circumvention of anoxia during arrest of cerebral circulation for intracranial surgery. *J. Neurosurg.*, 1955, *12:* 226–239.
3. Swan, H., and Zeavin, I. Cessation of circulation in general hypothermia. III. Technics of intracardiac surgery under direct vision. *Ann. Surg.*, 1954, *139:* 385–396.

THE IMPORTANCE OF THE DEEP CEREBRAL VEINS IN CEREBRAL ANGIOGRAPHY

WITH SPECIAL EMPHASIS ON THE ORIENTATION OF THE FORAMEN OF MONRO THROUGH THE VISUALIZATION OF THE "VENOUS ANGLE" OF THE BRAIN

PAUL M. LIN, M.D., JOHN F. MOKROHISKY, M.D., HERBERT M. STAUFFER, M.D., AND MICHAEL SCOTT, M.D.

Departments of Neurosurgery and Radiology, Temple University Hospital and School of Medicine, Philadelphia, Pennsylvania

(Received for publication February 2, 1955)

THE emphasis in cerebral angiography has until recently been centered on the arterial phase.[5,8,9,12,17,18,27]

Except for the demonstration of tumor stain or arteriovenous vascular anomalies, the diagnosis of space-occupying lesions had depended on the displacement of the cerebral arterial system. Venous patterns were held to be too variable for their displacement to be evaluated in terms of space-taking lesions. In 1937, Moniz[19,20] stressed the value of the venous phase of the cerebral angiogram in the diagnosis of tumors and more recently, Krayenbühl and Richter,[15] Richter,[23] Johanson,[13,14] Riemenschneider and Ecker,[22] and Wolf *et al.*[28] have emphasized this phase of the angiogram in their publications.

The value of cerebral angiography in the diagnosis of space-occupying lesions has often been compared favorably with pneumoencephalography, except in cases of deep-seated supratentorial and infratentorial lesions, in which the latter was believed to be superior. The reason for this deficiency is the fact that sizable branches of the arterial system do not penetrate to the deeper structures. However, ordinarily, in the brain, the arteries and veins do not run together and it is, therefore, conceivable that a space-occupying lesion may displace one system without disturbing the other. As Richter[23] and Johanson[13,14] have recently pointed out, the deep cerebral veins are often well visualized in routine cerebral angiography, especially the internal cerebral vein and its branches which drain the deeper cerebral area. Unlike the cortical veins, they are more constant in their appearance and anatomical location. The deep cerebral veins, therefore, have an important place in the diagnosis of deep-seated cerebral lesions and possibly in infratentorial lesions.

The purpose of this paper is to stress the importance of cerebral phlebography and especially the evaluation of the deep cerebral veins in the diagnosis of brain tumors. A study of the changes of the configuration and the position of the internal cerebral vein and its branches in various types of deep-seated lesions is presented. An attempt is also made to assess the signif-

icance of the position of the foramen of Monro, localized by visualization of the "venous angle" of the brain, in various types of cerebral space-taking lesions.

ANATOMY OF THE DEEP CEREBRAL VEINS

The deep cerebral veins are the choroid veins, the striothalamic veins, the internal cerebral veins, the great cerebral vein of Galen and the basal vein of Rosenthal[1,3,11] (Figs. 1, 2, 3, 4 and 5). Embryologically,[11] the deep veins take origin from the anterior plexus and the middle plexus of the primary head vein. When the cerebral hemispheres increase in size the dura

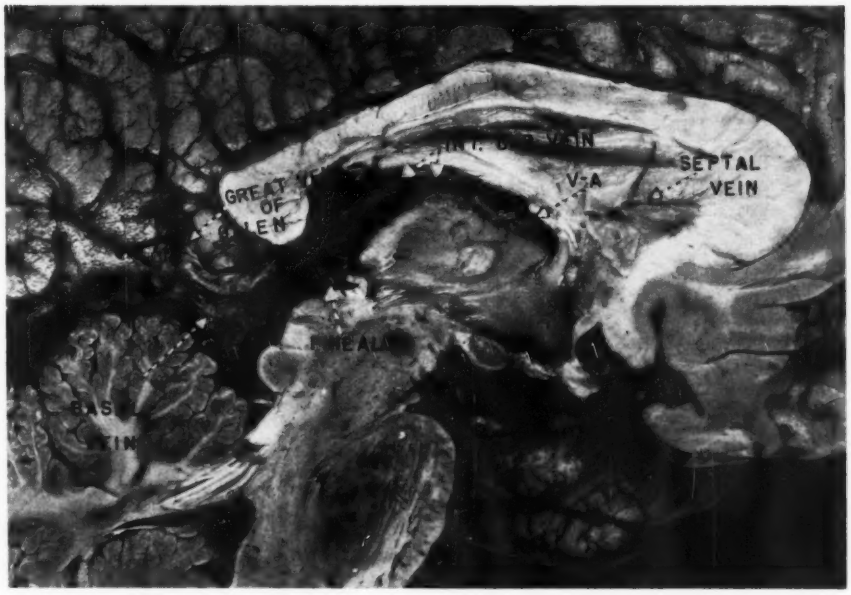


FIG. 1. Sagittal section of brain showing the deep cerebral veins and their surrounding structures.

mater is compressed between them in the form of the fold that later forms the falx. As the fold is formed the conjoined anterior and middle plexuses are carried into contact with their counterpart on the other side and are finally resolved into the superior and inferior sagittal sinuses. The smaller vessels of the plexuses which retain their connections with the pia mater are transformed into the internal cerebral vein and the great cerebral vein of Galen. From some of the ventral tributaries the inferior cerebral vein is formed which later becomes the basal vein of Rosenthal.

The deep cerebral veins receive their arterial blood supply from the anterior choroidal artery of the internal carotid artery, the lenticulostriate artery of the middle cerebral artery, the recurrent artery of Heubner of the

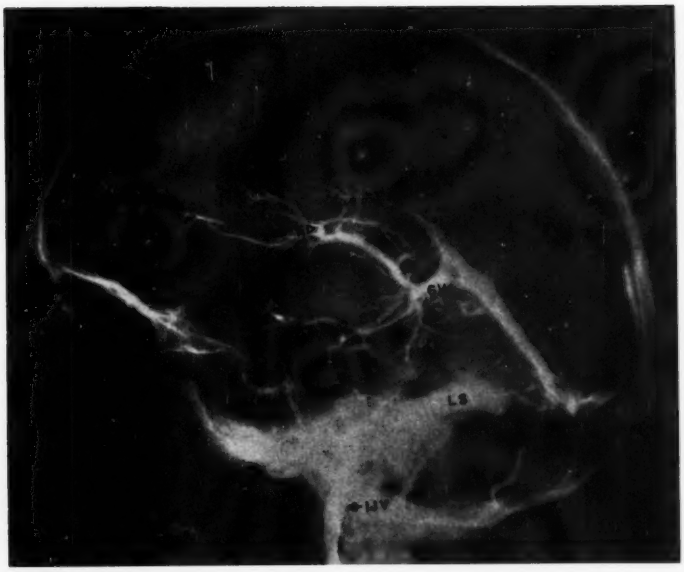


FIG. 2. Normal deep cerebral venogram—lateral view. (Injected specimen.)

FIG. 3. Normal deep cerebral venogram—reverse Water's view. (Injected specimen.)

anterior cerebral artery, and the posterior choroidal artery of the posterior cerebral artery. The latter may sometimes originate from the basilar artery. From the circle of Willis, numerous small perforating arteries also supply the deep cerebral structures. The posterior choroidal artery serves the choroid plexus of the third ventricle and, with the anterior choroidal artery, supplies that of the lateral ventricle. Besides supplying the choroid plexuses the two choroidal arteries, together with the recurrent artery of Heubner and the

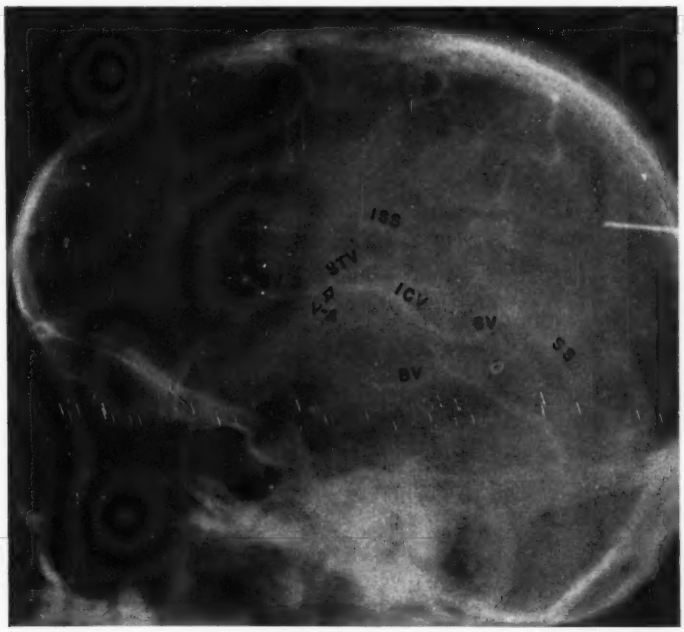


FIG. 4. Normal cerebral venogram—lateral view. V-A = venous angle. STV = striothalamic vein. ICV = internal cerebral vein. SV = septal vein. GV = great vein of Galen. BV = basal vein of Rosenthal. ISS = inferior sagittal sinus. SS = straight sinus.

lenticulostriate artery, supply the thalamus, the internal capsule and the basal ganglia (Figs. 1, 3, and 14).

The venous blood from the choroid plexus of the lateral ventricle empties into the striothalamic vein via the superior choroidal vein. The striothalamic vein runs parallel to the terminal portion of the choroidal artery along the lateral inferior wall of the lateral ventricle in the groove formed between the caudate nucleus and the thalamus. The striothalamic vein runs forward and reaches the foramen of Monro where it takes a sharp backward turn and joins at this point with the septal vein (vein of the septum pellucidum) and several small efferent veins from the choroid plexus of the third ventricle.

The vein continues to form the internal cerebral vein posteriorly and slightly inferiorly.

The "striothalamic vein" (a term widely used in the European literature in describing the deep cerebral veins) is actually the same as the "terminal vein" except that the striothalamic vein includes the superior choroidal vein as its tributary. The terminal vein as a major branch of the striothalamic vein receives the drainage from the deep frontal lobe, the corpus callosum, the corpus striatum, the internal capsule and the thalamus. Its branches run

FIG. 5. Normal cerebral venogram—anteroposterior view. SSS = superior sagittal sinus. V-A = venous angle. ICV = internal cerebral vein. STV = striothalamic vein. BV = basal vein of Rosenthal. GV = great vein of Galen.

with the callosal fibres above the rostrum and join the rest of the striothalamic vein that runs anteriorly from the choroid vein at or near the foramen of Monro. The terminal vein also receives the transverse caudate vein which drains the caudate nucleus and the thalamus. This runs subependymally, anteriorly and inferiorly between the upper surface of the caudate nucleus and the lower surface of the corpus callosum. The septal vein travels along the anterior and medial aspect of the anterior horn. It is usually curved but can be straight when passing backward to meet the striothalamic vein. This vein receives drainage from the corpus callosum and the deep frontal lobe. The sharp angle, named by Richter the "venous angle of the brain" (Figs. 1, 2, 4, and 6) is the point at which the striothalamic vein

turns mesially and slightly inferiorly, hugging the posterior superior border of the foramen of Monro to form the origin of the internal cerebral vein. The anterior convexity of this turn, or the venous angle, signifies radiographically the posterior border of the foramen of Monro. The paired internal cerebral veins run posteriorly and paramedially within the tela choroidea in the roof of the third ventricle.

The course of the internal cerebral vein in the lateral view has the pattern of a flattened "sine wave" (Figs. 2, and 4). Along their course the internal cerebral veins receive tributaries from the choroid plexus of the third

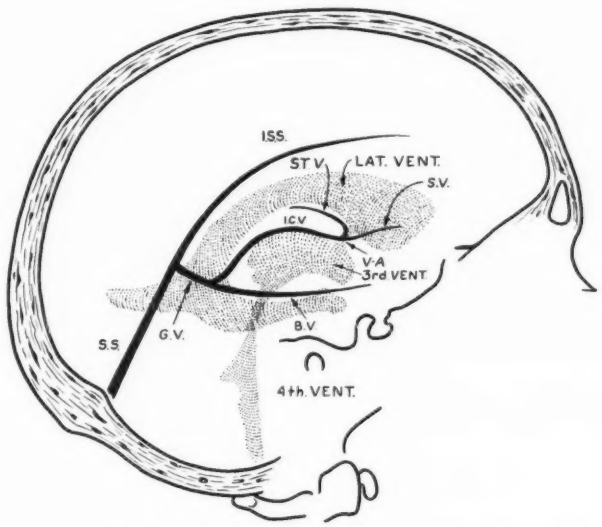


FIG. 6. Diagrammatic drawing showing relationship of deep cerebral veins with the ventricular system. ISS = inferior sagittal sinus. SS = straight sinus. GV = great vein of Galen. BV = basal vein of Rosenthal. ICV = internal cerebral vein. STV = striothalamic vein. V-A = venous angle. SV = septal vein.

ventricle and from the fornix and corpus callosum. Frequently, the internal cerebral vein receives drainage from the ependymal lining of the posterior horn. Johanson called the vein draining the posterior horn in this fashion, the posterior ventricle vein.[13] This vein usually joins the internal cerebral vein at its posterior third. Johanson also described another branch of the internal cerebral vein which takes its origin usually at the middle or anterior third of the internal cerebral vein. Either of these veins can easily be mistaken for the striothalamic vein if the latter is not filled with the contrast medium.

The paired internal cerebral veins join the basal veins of Rosenthal from each side posteriorly. The four veins eventually drain into a single midline vein, the great cerebral vein of Galen, beneath the splenium and above the

corpora quadrigemina (Fig. 6). The great cerebral vein joins the inferior sagittal sinus at the edge of the tentorium to form the straight sinus which then enters into the confluens sinuum (torcular Herophili). The basal vein of Rosenthal begins at the anterior perforated substance. It is formed by the union of the anterior cerebral vein, the deep middle cerebral vein and the striate vein. It passes backward and upward in the cisterna ambiens around the cerebral peduncle. It receives along its course the tributaries of the choroid plexus of the temporal horn. The basal vein drains the basal portions of the diencephalon and the mesencephalon which include the anterior perforated substance, the tuber cinereum, the mammillary body, the posterior perforated substance, the uncus and the cerebral peduncle.

The great cerebral vein of Galen is a single midline structure running under the splenium in the cisterna venae magnae cerebri above the quadrigeminal bodies. Occasionally it receives a pair of occipital veins which receive their drainage from the inferior and mesial surfaces of the occipital lobes. The great cerebral vein may also receive tributaries from the posterior cingulate gyri of each side, the pineal body, the corpora quadrigemina and the upper surface of the cerebellum via the superior cerebellar vein. The posterior portion (ampulla) of the great vein of Galen is fixed to the anterior edge of the rigid juncture of the falx and the tentorium. The great vein runs between the corpora quadrigemina and the splenium of the corpus callosum and joins the inferior sagittal sinus at an acute angle. This angle is of little clinical importance as there are too many variations in normal individuals. The angle is more acute in brachycephaly and wider in dolichocephaly.

The inferior sagittal sinus runs along the entire course of the inferior margin of the falx. There is a large number of normal variations in the configuration and course of the inferior sagittal sinus. It is usually curved like a bow with an upward convexity but it may sometimes run in a straight line. The straight sinus, which is situated along the midline of the tentorium, drains into the torcular Herophili at an angle varying considerably in normal subjects.

IMPORTANCE OF DEEP CEREBRAL VEINS IN DIAGNOSIS OF SPACE-OCCUPYING LESIONS

Because of their attachment to the stiff falx and tentorium, the great cerebral vein of Galen, the inferior sagittal sinus and the straight sinus do not change their position to any great extent in cases of space-occupying lesions. Tumors in the locality of these structures may distort their normal configuration or sidetrack their normal venous tributaries. In the anteroposterior projection, the inferior sagittal sinus is displaced laterally by hemispheric space-taking lesions to a lesser degree than the corresponding internal cerebral vein and the pineal body. The internal cerebral vein and its branches have a relatively constant anatomical position and configuration with little normal variation. The fact that the great cerebral vein of Galen has a fixed anchorage at its posterior attachment to the border of the tentorium makes

the internal cerebral vein and its tributaries more vulnerable in changing their configuration with any sizable space-occupying lesions. The internal cerebral vein is readily compressed toward, or stretched away from, its fixed dorsal attachment.

The internal cerebral vein, because of its anatomical position in the roof of the third ventricle on the superomedial aspect of the thalamus, plays an important role in the diagnosis of deep-seated tumors including lesions of the third ventricle (Fig. 6). Infiltrating lesions of the basal ganglia and tumors of the third ventricle have a tendency to distort the configuration

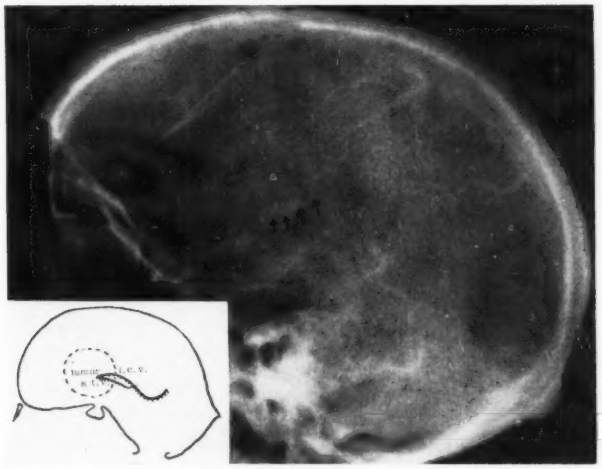


FIG. 7. *J.P.* Deep frontal lobe glioblastoma involving the basal ganglia. Note that the striothalamic vein is depressed to a lower level than the internal cerebral vein.

of the internal cerebral vein without producing visible evidence of a space-occupying lesion in the arterial phase of the cerebral angiogram. This is because of the lack of sizable arteries in these areas, as previously pointed out. Richter[23] described the displacement of the internal cerebral vein as "the displacement syndrome of the venous angle." He emphasized the change of the angle formed by the striothalamic vein and the internal cerebral vein in the presence of lesions in various positions in the brain. The angle may be flattened or become a sharp angle (Fig. 7) when it has been displaced from the periphery. It may be widened when it has been stretched by an infiltrating lesion in the structures lying between the two veins, as in the case of a glioma of the thalamus, a tumor of the third ventricle (Fig. 8) or a tumor of the corpus callosum.

Large space-occupying lesions of the periphery of the cerebral hemisphere can also displace the internal cerebral vein and the foramen of Monro as visualized by the "venous angle," just as a shift of the calcified pineal body may occur.

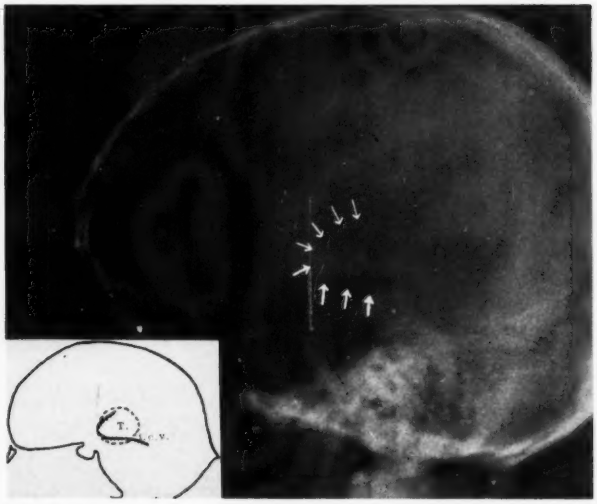


FIG. 8. *J.H.* Colloid cyst of the third ventricle. The internal cerebral vein is displaced downward by the tumor.

A tumor of the frontal lobe displaces the internal cerebral vein and the venous angle posteriorly (dorsally). The internal cerebral vein may be shortened and compressed like an accordion ("concertina-like"[13]). The septal vein and the terminal vein may individually be distorted if the tumor is of the deep infiltrating type (Fig. 9).

A precentral lesion or tumor of the convexity naturally would depress the

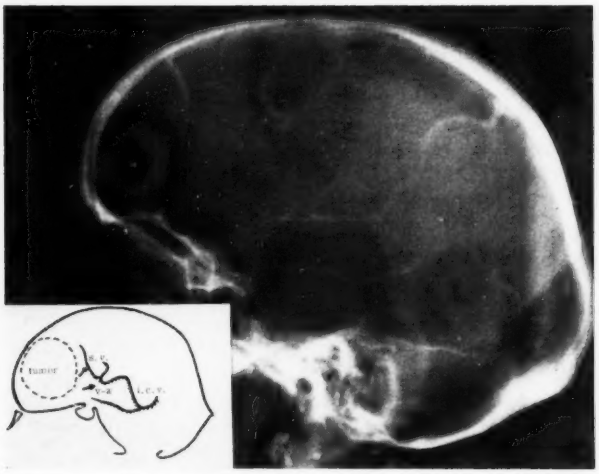


FIG. 9. *V.G.* Large frontal lobe cystic glioblastoma. The internal cerebral vein and the venous angle are displaced posteriorly and present a "concertina-like" appearance.

internal cerebral vein, the striothalamic vein and the venous angle (caudal displacement). The laterally placed striothalamic vein may run at the same level as the internal cerebral vein in the lateral projection, or may be even lower than the internal cerebral vein (Fig. 7), especially in the case of a tumor within the lateral ventricle, such as an ependymoma.

An occipital tumor (Fig. 10) would displace the venous angle anteriorly (ventrally), but would rarely distort its configuration. This is probably because of the inclined stiff tentorium which serves as a hard partition between the occipital lobe and the deep cerebral veins. A tumor of the splenium of the corpus callosum has a tendency to depress the internal cerebral vein or

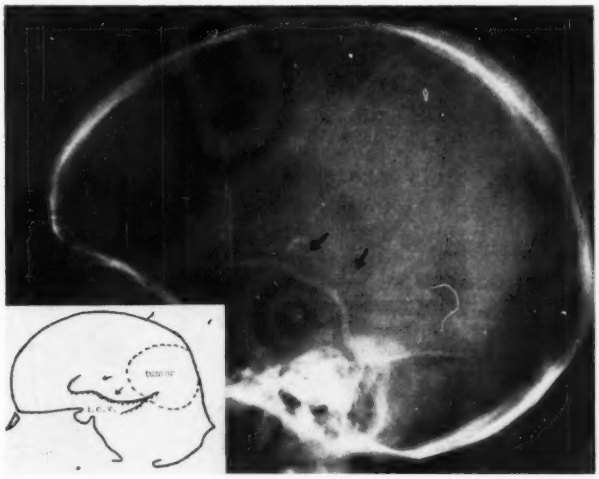


FIG. 10. *D.S.* Huge meningioma of right occipital lobe. The internal cerebral vein and venous angle are displaced anteriorly and inferiorly.

flatten it, while in the presence of a pinealoma both internal cerebral veins would be displaced upward (cephalad) and laterally in their posterior portions. In a recent publication, Riemenschneider and Ecker[22] mentioned displacement of the great vein of Galen by a pinealoma. However, their schematic drawing of the roentgenogram shows that the great vein of Galen is in a relatively normal position while the actual displacement appears to have occurred in the posterior third of the internal cerebral vein. Johanson, in his monograph on the deep cerebral veins,[14] stated that the internal cerebral veins rather than the vein of Galen are displaced by pinealomas. As previously noted, the great vein of Galen is a short structure fixed at the junction of the tentorium and the falx. It is for this reason that little or no displacement of this structure occurs when there is a nearby space-taking lesion; it is more likely that the adjacent tributaries such as the internal cerebral vein and the basal vein of Rosenthal will exhibit more definite and significant changes as visualized in the phlebogram.

In the case of a tumor of the third ventricle, one would expect the two

internal cerebral veins to be elevated, stretched and displaced laterally in the anteroposterior projection. This is contrary to the situation occurring with a deep-seated tumor of the thalamus, when the internal cerebral vein is displaced upward and mesially toward the midline or across the midline to the other side as visualized in the anteroposterior projection. In the case of a colloid cyst of the third ventricle (Fig. 8) the internal cerebral vein is stretched and displaced anteriorly and inferiorly by the cyst, which supposedly originates from the paraphysis in the tela choroidea.

Temporal lobe lesions, because of their anatomical location, may show a marked displacement of the internal cerebral vein toward the opposite side in the anteroposterior projection (Fig. 11) without any displacement of the

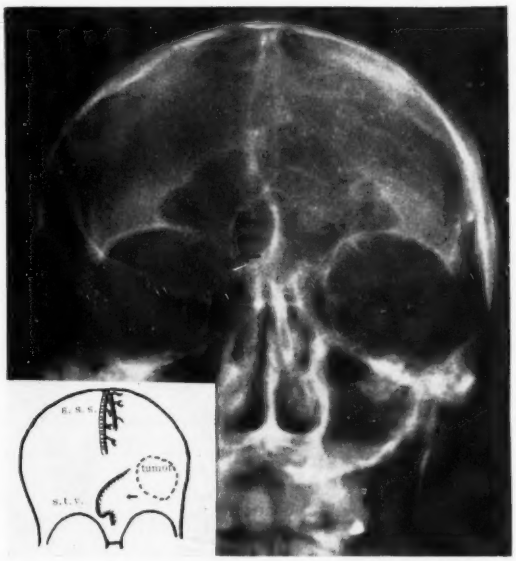


FIG. 11. *T.S.* Right temporal lobe glioblastoma. The internal cerebral vein is displaced to the left of the midline. Anteroposterior view.

venous angle in the lateral projection; the internal cerebral vein, however, is commonly markedly stretched and loses its smooth sinuous configuration.

Craniopharyngiomas, pituitary tumors, aneurysms or other basal tumors may displace the internal cerebral vein and the venous angle cephalad and dorsad. The septal vein and the internal cerebral vein are elevated while the internal cerebral vein and the striothalamic vein may appear to be displaced toward each other in lesions of this character.

Since we do not perform carotid angiograms routinely in patients with infratentorial lesions, we have not encountered any displacement of the internal cerebral vein in such cases. However, it is conceivable that in the

case of a large tumor of the pons or of the vermis of the cerebellum, the internal cerebral vein might be displaced upward and forward (cephalad and ventrad). Also one would expect to see some significant changes in the basal vein of Rosenthal.

Each internal cerebral vein runs paramedially along the roof of the third ventricle. The anterior part of the vein is in the axis of the roentgen beam in the anteroposterior projection and therefore in this view this part of the internal cerebral vein is visualized as a dense round spot beneath a similar one formed by the inferior sagittal sinus. The paired internal cerebral veins are 2 to 3 mm. apart so that, for all practical purposes, each may be considered to be situated at a distance of 1 mm. from the midline (Figs. 3 and 4). This position is of importance in measuring the lateral displacement of these veins in the anteroposterior projection. When the head is rotated at the time the angiogram is exposed, stereoscopy aids in determining the presence or absence of lateral shift of these veins through the relationship of the internal cerebral vein to other fixed midline structures such as the superior and inferior sagittal sinuses, the tuberculum sellae and the crista galli.

The internal cerebral vein, the anterior cerebral artery and the pineal body are considered midline structures as visualized in the anteroposterior projection. All three of these midline structures may be visualized. Displacement of one without displacement of the other may help in localization of a tumor, since the three structures are situated in various positions along the mid-sagittal plane.

The basal vein of Rosenthal, which originates in the anterior perforated space from the union of the anterior cerebral vein, the deep middle cerebral vein and the inferior striate vein, travels around the cerebral peduncle in the cisterna ambiens and receives along its course the choroid veins from the choroid plexus of the temporal horn. The visualization of this vein in cerebral phlebogram in the anteroposterior projection has a significance similar to the demonstration of calcified choroid plexuses in determining whether a tumor in the temporal area is situated in the temporal lobe or in deeper structures. The vein would be expected to be displaced laterally in a mid-brain lesion and displaced upward in a basal space-occupying lesion or a massive infratentorial tumor.

LOCALIZATION OF FORAMEN OF MONRO THROUGH VISUALIZATION OF "VENOUS ANGLE" OF BRAIN

The importance of the orientation of the calcified pineal body as an aid in the roentgenologic localization of space-occupying lesions is well known.[6,7,10,21] Despite the recent advances in pneumoencephalography and angiography, in many instances the combination of a significant pineal shift in addition to an accurate history and neurologic findings, provides sufficient diagnostic evidence to warrant neurosurgical intervention in the case of a suspected intracranial space-occupying lesion.

We know that only approximately 50 per cent of all pineal bodies are

sufficiently calcified to permit radiographic visualization[24] and only 50 to 70 per cent of those visualized exhibit calcification sufficiently discrete to permit adequate orientation measurements in both the anteroposterior and lateral projections. The "anterior convexity point" of the striothalamic vein or the "venous angle" of the brain (V-A) localizes the posterior border of the foramen of Monro which, in normal subjects, is an anatomically constant structure with a constant position just as is the pineal body. If orientation measurements in the lateral projection using the anterior convexity point of the "venous angle" can be made as has been done for the calcified pineal,[26] it

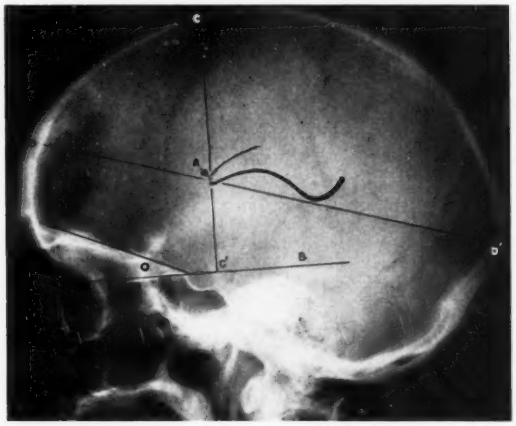


FIG. 12. Diagram showing the measurements used in the orientation of the "venous angle."

would help in localization of space-occupying lesions by cerebral angiography, especially in the following situations:

1. Infiltrating deep-seated lesions when the arterial pattern is not disturbed.

2. When the internal cerebral vein is displaced but not distorted.

3. When the anterior projection is unsatisfactory because of rotation, especially when stereoscopic projections are not available.

The Vastine-Kinney chart for the orientation of the pineal body[26] is most widely used today, despite many modifications added since the original article was published in 1927. The following is a study of the orientation of the anterior convexity point of the venous angle of the brain employing a method similar to that of Vastine and Kinney for pineal body orientation (Fig. 12).

(1) Select the anterior convexity point along the "venous angle" (A). This is the point at which the striothalamic vein joins the internal cerebral vein and is called the "venous angle" of the brain. The anterior convexity point is usually directed anteriorly but sometimes it may point antero-inferiorly. The angle is

usually quite acute so that there is no difficulty in choosing this point. If the angle takes the form of a large arc, one should choose the anterior inferior convexity point of the arc for the orientation study since the internal cerebral vein has a relatively straight course until it reaches the foramen of Monro where it begins the sweep that forms the venous angle.

(2) Draw the base line (B), the line that joins the nasion and the tuberculum sellae, and extend the line beyond the tuberculum sellae.

(3) Draw a perpendicular line from the base line (B) passing through point (A) to reach the inner table of the skull at the vault. The distance from the inner table of the vault to point (A) is called C and the distance from the inner table of the vault to the base line (B) is called C′.

(4) The distance from point A to the inner table of the frontal bone (the longest distance) is called D.

(5) The longest anteroposterior diameter of the skull (D′) is measured from the inner table of the frontal bone to the inner table of the occipital bone. In the event that slight rotation of the skull has resulted in visualization of two inner tables of the frontal bone, the midpoint between the two is employed for measurement.

(6) Chart C against C′ for determination of cephalic and caudal displacement of the venous angle.

(7) Chart D against D′ for determination of ventral and dorsal displacement of the venous angle.

(8) The angle formed between the floor of the anterior fossa and the base line at the tuberculum sellae is O. The average of this angle O is 23 degrees. Should the nasion not be visualized either because of poor penetration of this portion of the skull or because this point is projected beyond the border of the film, one can reconstruct the base line utilizing the average angle O (23 degrees) and a line corresponding to the floor of the anterior fossa.

MATERIAL

The measurements for this study were made from cerebral angiograms exposed in the biplane stereoscopic serial device (Chamberlain).[2,4] This device consists of two Fairchild roll film magazines and two rotating anode roentgen tubes arranged at right angles to each other so that simultaneous anteroposterior and lateral projections can be secured. A mechanism shifts both roentgen tubes between exposures and during the film transport so that, in each projection, each exposure on the roll is stereoscopic with the exposure preceding it and following it. The time lapse between exposures is 0.6 second. The distance from the target of the roentgen tube to the film is 40 inches, and the distance from the center of the patient's head to the film in the lateral projection is approximately six inches resulting in a magnification factor of approximately 46/40. For cerebral angiography 12 exposures in both the anteroposterior and lateral projections are made routinely. The injection of the contrast material begins immediately after the first film is exposed; an 18 gauge needle is employed and 10 cc. of 30 per cent Urokon sodium solution are injected as rapidly as possible.[16]

Two hundred cerebral angiograms, including both normal and abnormal

cases, have been studied. The visualization of the various deep cerebral veins obtained is analyzed in Table 1.

TABLE 1

Frequency of visualization of deep cerebral veins in a study of 200 cases

	Cases	Per Cent
Superficial cortical veins	179	89
Septal vein	61	30
Striothalamic vein	131	65
Internal cerebral vein	153	76
Great vein of Galen	143	71
Basal vein of Rosenthal	136	69

Since cerebral angiograms are not performed knowingly in normal individuals, it is extremely difficult to compile a group of normal cerebral angiograms. The "normal" angiograms in this study are those of patients with normal or insignificant neurological findings, normal electroencephalograms, and normal cerebrospinal fluid studies. It was not, of course, possible to do pneumoencephalograms in all of these patients to verify their normality. Patients with histories of old spontaneous subarachnoid hemorrhage with or without demonstrable aneurysms are also included in this series of normal angiograms, provided that at the time of examination there was no evidence of fresh hemorrhage, hematoma formation or abnormal neurological sign.

Charts were made of the orientation of the venous angle of the brain using the same principles employed in construction of the Vastine-Kinney chart for pineal body orientation (Fig. 13). The two limiting lines designat-

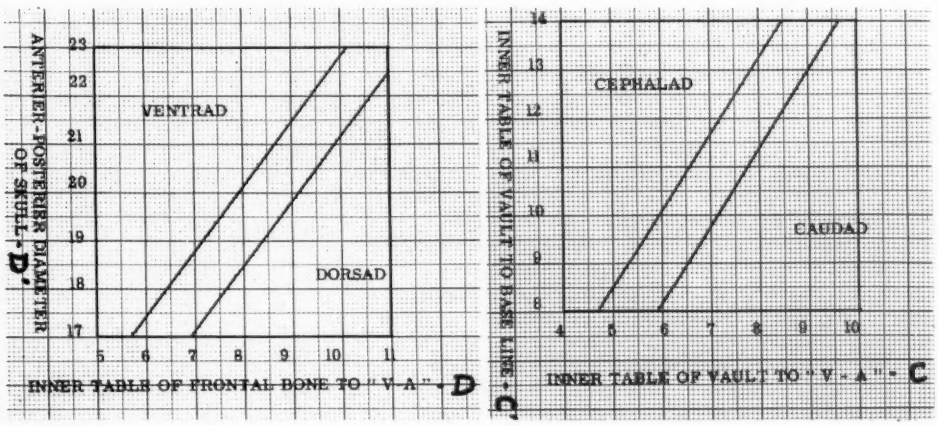
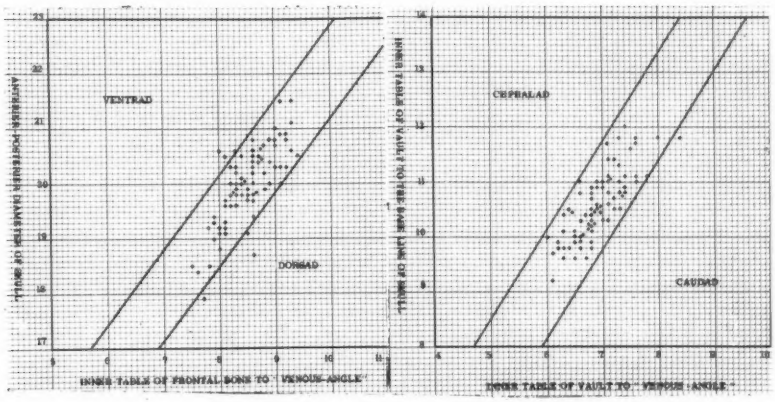


FIG. 13. Venous-angle orientation chart showing range of normal deviation in both ventrodorsad and cephalocaudad directions.

ing the normal limits of position of the venous angle are 12 mm. apart in the dorsal-ventral orientation chart (Fig. 14)—11 mm. apart in the Vastine-Kinney chart—with 92.3 per cent of the normal falling between these lines. In the cephalic-caudal orientation chart (Fig. 15) the distance is also 12 mm. apart—12 mm. in the Vastine-Kinney chart—with 98.7 per cent of the normal cases falling between the lines. The larger variation in dorsal-ventral orientation is caused by the variation in the shape of the skull (brachycephaly and dolichocephaly). In dolichocephaly the venous angle has the tendency to be displaced ventrad while in brachycephaly the venous angle tends to be displaced dorsally. There is the same difficulty in orientation of



FIGS. 14 and 15. Seventy-seven normal venous angle measurements plotted on chart to determine the normal range of deviation. The limiting lines denote the maximum deviation in (*left*) ventrodorsad and (*right*) cephalocaudad direction.

the pineal body in the presence of extreme dolichocephaly and brachycephaly.

The displacement of the venous angle in cases of intracranial space-taking lesions is shown in a study of 26 selected cases of proved space-occupying lesions (including 3 cases of internal hydrocephalus). In only 3 cases was the position of the venous angle within normal limits.

Seven cases of proved frontal lobe tumors are charted (Fig. 16). The venous angles are uniformly displaced posteriorly (dorsad). The internal cerebral vein may also be displaced upward (cephalad) or downward (caudad), depending on whether the tumor is situated at the convexity of the frontal lobe or at the base of the frontal lobe.

In cases of internal hydrocephalus with block either at the foramina of Magendie or Luschka, the aqueduct of Sylvius, or at the foramen of Monro, the internal cerebral vein and the venous angle are depressed (Fig. 17). Three cases of internal hydrocephalus and 5 cases of parietal convexity and

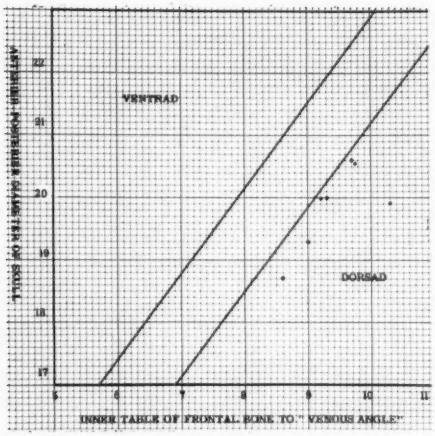


FIG. 16. Seven cases of frontal lobe tumors plotted on chart, showing posterior displacement of the venous angle.

parasagittal tumors are plotted in the cephalocaudal orientation chart showing their downward (caudal) displacement (Fig. 18).

Eight cases of parieto-occipital tumors are plotted (Fig. 19), 2 of which fall within the normal limiting lines of the dorsal-ventral orientation chart. The lack of ventral displacement of the internal cerebral vein and venous angle in these cases, as has been discussed previously, is attributed to the rigid partitioning effect of the tentorium. Associated downward (caudal) displacement of the venous angle is commonly seen.

Three cases of basal tumors are charted. They show slight upward (cephalic) shift of the venous angle (Fig. 20).

One point of importance in identifying the venous angle is that frequently the vein of the posterior horn or a branch of the internal cerebral vein may be mistaken for the striothalamic vein. The following observations

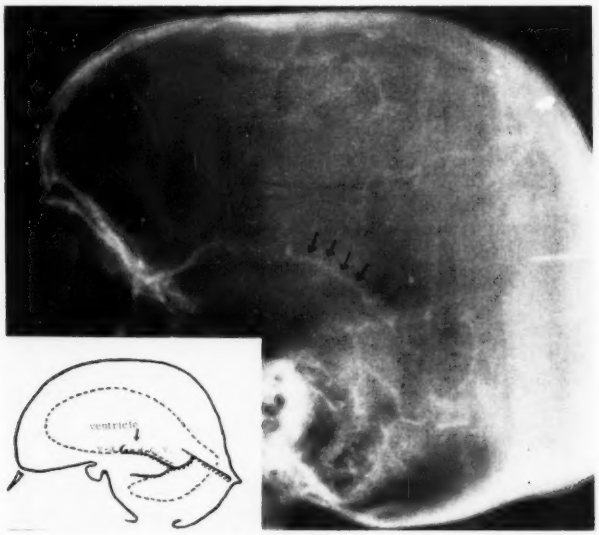


FIG. 17. *I.S.* Hydrocephalus. The internal cerebral vein is flattened and displaced downward because of enlargement of the lateral ventricles.

should aid in differentiating the two veins:

1. The vein of the posterior horn takes off from the middle of the internal cerebral vein and should the internal cerebral vein beyond this point not be filled, one would observe that the internal cerebral vein appears unusually short (Fig. 21). Although one can find the internal cerebral vein shortened in cases of large frontal lobe tumors, in these cases the internal cerebral vein loses its smooth sinuous configuration and, instead, it is often compressed together in accordion-fashion ("concertina-like," Johanson).

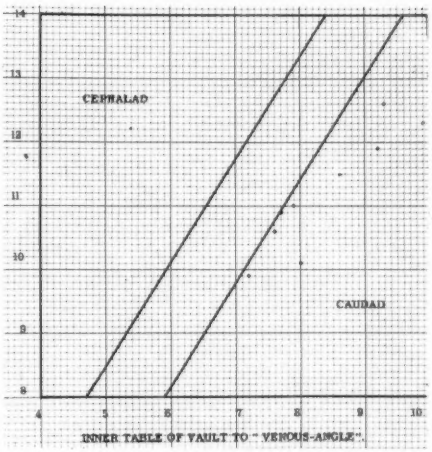
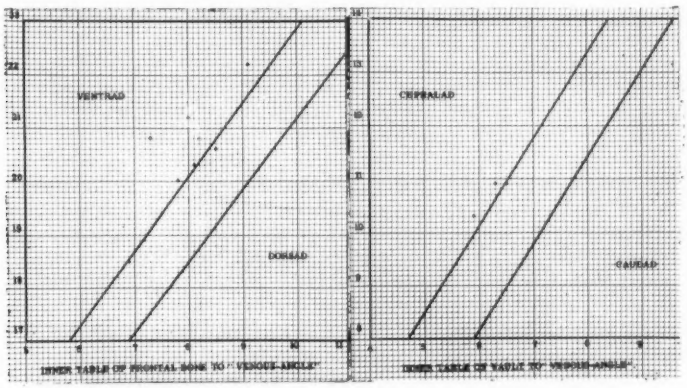


FIG. 18. Cases of internal hydrocephalus (3) and parasagittal and convexity tumors (5) plotted on chart, showing downward displacement of the venous angle.

2. The junction of the striothalamic vein and the internal cerebral vein ordinarily appears in the lateral projection as a smooth though fairly sharp curve and the veins then run parallel to each other. The other branches of the internal cerebral vein usually take off at a right angle or a sharp acute angle.

3. The presence of the septal vein helps to identify the striothalamic vein.

4. The vein of the posterior horn is usually present when the posterior cerebral artery of that side is filled in the arterial phase.



FIGS. 19 and 20. (*Left*) Eight cases of parieto-occipital tumors plotted on chart, showing forward displacement of the venous angle. (*Right*) Three cases of tumors of the base of the brain, showing upward displacement of the venous angle.

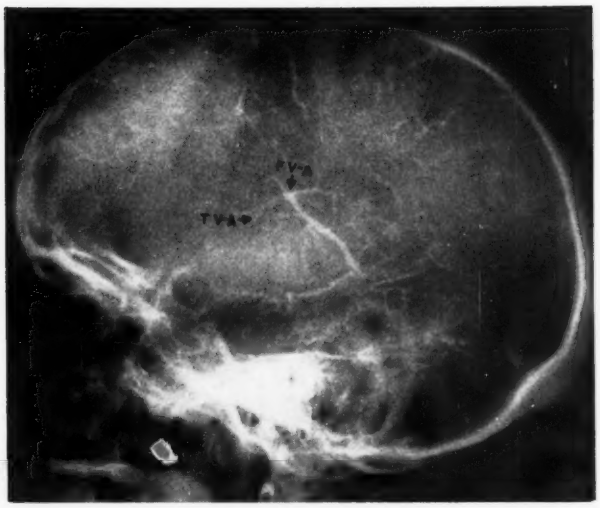


FIG. 21. False venous angle. The true venous angle (TV-A) is 17 mm. antero-inferior to the false venous angle (FV-A).

DISCUSSION

The study of the deep cerebral veins in the cerebral phlebogram is extremely important in the roentgen diagnosis of deep-seated space-occupying lesions. Large space-occupying lesions of the periphery of the cerebral hemispheres usually show sufficient displacement in the arterial phase even though they also show definite demonstrable displacement of the deep cerebral veins. However, there is one exception to this statement: occasionally, an occipital lobe tumor may not be visualized by the carotid angiogram when there is a lack of filling of the posterior cerebral artery and the anterior cerebral artery is not displaced to the opposite side, the lesion being situated too far posteriorly. A significant forward (ventral) shift of the venous angle in these cases in addition to the presence of a definite homonymous hemianopsia may warrant further contrast study such as pneumoencephalography.

The internal cerebral vein has a constant anatomical configuration and position. However, there are normal deviations. To establish a diagnosis of a deep-seated lesion on radiographic findings with respect to the internal cerebral vein and its branches alone, without any knowledge of a complete neurological examination would be hazardous. Because of the compactness of the anatomical structures in the deep cerebral area, a space-occupying lesion in these areas invariably presents a neurologic deficit. Therefore, when one encounters slight change in the configuration or slight displacement of the internal cerebral vein the latter can only be interpreted as of significance

when there are compatible neurologic findings. There is no substitute in the diagnosis of deep-seated space-occupying lesions or, for that matter, of any neurologic lesion for a careful, methodical and complete neurological examination. Roentgen studies may verify or supplement the clinical neurologic diagnosis; however, a definitely abnormal roentgenologic finding must, even though it may not conform entirely to the clinical neurological findings, be given great weight in arriving at the final diagnosis.

The study of the orientation of the foramen of Monro through visualization of the venous angle of the brain in the cerebral phlebogram shows that a good correlation exists between the displacement of the venous angle and the various positions of intracranial space-taking lesions. Basal tumors do not show any remarkable displacement of the venous angle cephalad to the normal limiting lines of the cephalocaudal orientation chart. This is to be expected as the lesions in this area are relatively small when discovered. Hence, a more refined method of measurement, such as determining the average normal distance from the venous angle to the posterior clinoid, might be of value in orientation of lesions in this area.

It is extremely important to take into consideration normal variation in the position of the foramen of Monro as visualized through the venous angle of the brain in the cerebral phlebogram.[14] If one is familiar with the normal position and configuration of the deep cerebral venous system, it should be possible to detect any gross displacement or alteration of its general configuration from the normal in the case of an intracranial space-occupying lesion. This is probably more important in arriving at a diagnostic opinion from a cerebral phlebogram than relying completely on measurements of a point or a structure.

Since visualization of the deep cerebral veins can be obtained in a relatively high percentage of cases in routine cerebral angiography (75 per cent) and since cerebral phlebography has a definite place in the diagnosis of brain tumors, one should certainly always try to obtain a satisfactory venous phase of the cerebral angiogram.

The time of the appearance of the venous phase in cerebral angiography varies tremendously from individual to individual. It may vary from 2 seconds to 8 seconds. The reason for the marked variations in the circulation time may be found in the variation of individual response to the contrast material, sensitivity of the cerebral vascular system, the rate of injection and the effect of the various types of intracranial lesions. Serial angiography with an exposure interval of 1 second or less is desirable. If serial angiography is not available, it is suggested that films be exposed at 2, 4, 6 and 8 seconds from the beginning of the injection in an effort to include satisfactory visualization of the venous phase. Special attempts should be made to obtain a satisfactory phlebogram when a deep-seated cerebral lesion is suspected.

SUMMARY

The anatomy of the deep cerebral veins has been discussed.

The importance of the deep cerebral veins in the diagnosis of space-occupying lesions by cerebral angiography has been stressed. The need for obtaining a technically satisfactory phlebogram in routine cerebral angiography then becomes obvious.

Cerebral phlebograms with satisfactory visualization of the internal cerebral vein and the venous angle of the brain were obtained following a single injection of 10 cc. of 30 per cent "Urokon sodium" in 75.5 per cent of cases in the study of a series of 200 cerebral angiograms performed with the stereoscopic serial angiographic device (Chamberlain): 10.5 per cent showed no visualization of the venous phase; 13 per cent showed visualization of the superficial cortical veins without satisfactory visualization of the deep cerebral veins.

An attempt was made to establish an orientation chart for the foramen of Monro through the visualization of the "venous angle" of the brain in the cerebral phlebogram, using the same principles employed in constructing the Vastine-Kinney chart for the position of the pineal body. Seventy-seven "normal" cerebral phlebograms were used to establish the normal limits of position for the venous angle. The normal deviation is 6 mm. in any direction.

Twenty-six cases of proved space-occupying lesions were studied. The orientation of the venous angle in this group indicates that the foramen of Monro can be displaced by any sizable space-occupying lesion.

While the orientation chart so constructed provides a useful basis for study of the position of the foramen of Monro, it is pointed out that, with experience, inspection of the phlebogram and evaluation of the relationship of the internal cerebral vein and its tributaries to the landmarks in the skull, as well as the configuration of the internal cerebral vein itself, may be of greater diagnostic value than any absolute measurement made from the roentgenograms.

REFERENCES

1. Buchanan, A. MacG. Manual of anatomy. F. Wood Jones, Ed. *Baltimore: Williams & Wilkins Co.*, 1950, 8th ed., viii, 1616 pp.
2. Chamberlain, W. E., and Stauffer, H. M. A new device for stereoscopic cerebral and cardiac angiography. *Trans. Coll. Phycns. Phila.*, 1951–1952, *19:* 148.
3. Cunningham, D. J. Text-book of anatomy. J. C. Brash, Ed. *London: Oxford Univ. Press*, 1951, 9th ed., i, 1604 pp.
4. Dotter, C. T., and Steinberg, I. Angiocardiography. *New York: Paul B. Hoeber, Inc.*, 1951, xix, 304 pp.
5. Dyes, O. Angiographie. *Fortschr. Röentgenstr.*, 1941, *63:* 63–84.
6. Dyke, C. G. Indirect signs of brain tumor as noted in routine roentgen examinations. Displacement of the pineal shadow. A survey of 3000 consecutive skull examinations. *Amer. J. Roentgenol.*, 1930, *23:* 598–606.
7. Dyke, C. G. The roentgen-ray diagnosis of diseases of the skull and intracranial contents. In: *Diagnostic roentgenology.* New York: Thomas B. Nelson & Sons, 1941, chap. 1, 1–34 BN.
8. Ecker, A. The normal cerebral angiogram. *Springfield, Ill.: Charles C Thomas*, 1951, xx, 190 pp.

9. Engeset, A., and Kristiansen, K. Cerebral angiography. In: *Modern trends in diagnostic radiology*. J. W. McLaren, Ed. London: Butterworth & Co., Ltd., 1948, xxi, 464 pp. (see pp. 348–369).
10. Fray, W. W. A roentgenological study of pineal orientation. III. A comparison of methods used in pineal orientation. *Amer. J. Roentgenol.*, 1938, *39:* 899–907.
11. Gray, H. Anatomy of the human body. C. M. Goss, Ed. *Philadelphia:* Lea & Febiger, 1954, 26th ed., 1480 pp.
12. Hodes, P. J., Perryman, C. R., and Chamberlain, R. H. Cerebral angiography. *Amer. J. Roentgenol.*, 1947, *58:* 543–582.
13. Johanson, C. The cerebral phlebogram by carotid angiography in cases of central brain tumours. *Acta radiol., Stockh.*, 1953, *40:* 155–172.
14. Johanson, C. The central veins and deep dural sinuses of the brain. An anatomical and angiographic study. *Acta radiol., Stockh.*, 1954, suppl. 107, 184 pp.
15. Krayenbühl, H., and Richter, Hs. R. Die zerebrale Angiographie. *Stuttgart: G. Thieme*, 1952, vii, 217 pp.
16. Lin, P., Murtagh, F., Wycis, H., and Scott, M. Carotid angiography with Urokon, using the Chamberlain bi-plane stereoscopic angiographic unit. Report of one hundred cases. *J. Neurosurg.*, 1953, *10:* 367–372.
17. List, C. F., Burge, C. H., and Hodges, F. J. Intracranial angiography. *Radiology*, 1945, *45:* 1–14.
18. List, C. F., and Hodges, F. J. Angiographic diagnosis of expanding intracranial lesions by vascular displacement. *Radiology*, 1946, *47:* 319–333.
19. Moniz, E. Déformations des sinus droit et longitudinal inférieur et des veines profondes du cerveau dans le diagnostic des néoplasies cérébrales. *Zbl. Neurochir.*, 1937, *2:* 214–224.
20. Moniz, E. Die cerebrale Arteriographie und Phlebographie. *Berlin: J. Springer*, 1940, viii, 413 pp.
21. Naffziger, H. C. A method for the localization of brain tumors—the pineal shift. *Surg. Gynec. Obstet.*, 1925, *40:* 481–484.
22. Riemenschneider, P. A., and Ecker, A. Venographic clues to localization of intracranial masses. *Amer. J. Roentgenol.*, 1954, *72:* 740–753.
23. Richter, Hs. R. Phlebography in brainstem tumours. *Acta radiol., Stockh.*, 1953, *40:* 182–187.
24. Stauffer, H. M., Snow, L. B., and Adams, A. B. Roentgenologic recognition of habenular calcification as distinct from calcification in the pineal body. Its application in cerebral localization. *Amer. J. Roentgenol.*, 1953, *70:* 83–89.
25. Trevano, M. Q. Sul valore dell'arteriografia cerebrale per la localizzazione del tumori del lobo temporale. *Radiologia med.*, 1942, *29:* 205–223.
26. Vastine, J. H., and Kinney, K. K. The pineal shadow as an aid in the localization of brain tumors. *Amer. J. Roentgenol.*, 1927, *17:* 320–324.
27. Wickbom, I. Angiography of the carotid artery. A study of its value in the tumour diagnosis, especially in comparison with pneumography. *Acta radiol., Stockh.*, 1948, suppl. 72, 90+141 pp.
28. Wolf, B. S., Newman, C. M., and Schlesinger, B. The diagnostic value of the deep cerebral veins in cerebral angiography. *Radiology*, 1955, *64:* 161–177.

THE DIAGNOSTIC SIGNIFICANCE OF RESTRICTED OCULAR MOTILITY IN CHILDREN

ROBERT G. MURRAY, M.D.

Division of Ophthalmology, Department of Surgery, University of North Carolina School of Medicine, Chapel Hill, North Carolina

(Received for publication March 28, 1955)

THIS study is an attempt to aggregate the etiological factors affecting eye movements in the patient under 16 years of age. In order that it would be of maximum diagnostic significance certain conditions were excluded from the study:

(1) Any congenital or developmental abnormality that affected ocular movements directly or indirectly. This includes all cases of nonparalytic strabismus.

(2) Presence of proptosis and a retrobulbar mass with inferred local involvement of the nerves or muscles.

(3) Poliomyelitis. A previous study of 516 cases by this writer[2] revealed only 8 patients under 16 years of age who had a restricted ocular motility.

The patients were selected from the records of two teaching hospitals.* Selection was based on the discharge diagnosis and was represented by 950 case records of encephalitis, meningitis, migraine, suppurative otitis media, intracranial tumors or tumor suspects, head trauma, diabetic neuropathy, demyelinizing diseases, cavernous sinus thrombosis, intracranial aneurysm, and myasthenia gravis, as well as all cases coded as affecting the neuromuscular mechanism controlling eye movements.

From these records 122 cases were found in which the ocular motility was affected. These did not include (1) patients whose general condition (particularly state of consciousness) precluded adequate evaluation, and (2) patients in whom there was no unanimity of opinion as to disturbed ocular motility.

The purpose of the study is to emphasize the marked difference in the diagnostic possibilities and prognosis when the child and the adult are affected by the same acquired lack of ocular motility. This difference is poorly documented in the literature although well recognized by some clinicians.

SIXTH NERVE PALSIES—TABLE 1

Of the 30 patients with cerebellar tumors, predominantly medulloblastomas (proven at operation), 15 exhibited only a unilateral 6th nerve involvement. The remainder showed a combination with either the 6th

* Duke University Hospital, Durham, North Carolina, and University of North Carolina Memorial Hospital, Chapel Hill, North Carolina.

nerve of the other side or the 7th nerve of the same or the opposite side (or both).

Of the 28 cases of pontine tumor, 9 were proved by postmortem examination, 4 by air study, and 2 by operation. In all of the remaining 13, the diagnosis was made by examination only; the patients died but no autopsy was performed. Two of the 28 patients had involvement of one 6th nerve, 10 of both 6th nerves. The other 16, with either unilateral or bilateral 6th nerve involvement, showed a variety of combinations with involvement of the 7th, 5th, 4th and 3rd nerves and superimposed gaze palsy of one or both sides.

In all 5 of the angle tumor cases there was involvement of the 5th, 7th and 8th nerves of the same side.

In the 4 cases in which no etiology was discovered, the palsies were unilateral. One of the patients had a simultaneous involvement of the 3rd

TABLE 1

Sixth nerve palsies in children

Etiology	Number of Cases
Cerebellar tumor	30
Pontine tumor	28
Cerebellopontine angle tumor	5
No etiology discovered	4
Secondary to otitis media	3
Meningitis	2
Head trauma	1
Trauma to posterior orbit	1
Intracranial aneurysm	1
Extradural tumor	1
Metastatic cerebral tumor	1
Primary cerebral tumor	1
Total	78

nerve on the same side. Both the 3rd and 6th nerve palsies cleared completely in 1 week. Four years later the child was alive and well with no evidence of further involvement. The other 3 patients showed only unilateral 6th nerve involvement. One was alive and well 10 years later, the palsy having cleared completely. This patient had an exploratory craniotomy while he was in the hospital, and no pathology was encountered.

In the 3 cases secondary to otitis media the palsies were unilateral. These, of course, represent Gradenigo's syndrome for which the pathogenesis is well understood.

It is felt that in the 2 cases caused by meningitis the background was similar.

The remainder showed unilateral 6th nerve involvement except the patient with intracranial aneurysm and the one with primary cerebral tumor.

Both of these had bilateral 6th nerve involvement. The former was found at operation to have an extensive aneurysm occupying the entire temporal fossa on one side, crossing over the midline to involve the 6th nerve on the other side. The latter had a primary cerebral tumor which had created so great an increase in supratentorial pressure that a pressure cone had developed both at the level of the tentorium and the foramen magnum. Assuming that the pons was displaced downwards together with the general descent of cerebrum and cerebellum it is conceivable that the thin 6th nerves were unduly stretched because of their dural attachment and lack of "slack."

In the cases of extradural tumor and metastatic cerebral tumor (sympathicoblastoma) the 6th nerve was involved directly along its course over the petrous portion of the temporal bone.

The patient with head trauma had a partial right 6th nerve palsy following injury, unassociated with other findings. The paralysis cleared spontaneously. Two years later the patient was alive and well with no further involvement.

In the 1 case of direct trauma, the nerves and muscles were injured by the entrance of a sharp-pointed instrument into the posterior orbit.

In the above discussion of the listed causes of 6th nerve palsies, the pathogenesis has been mentioned briefly in those cases in which it was obvious. However, paralyses caused by primary tumor arising within the cerebellum and pons or at the cerebellopontine angle require clarification.

Most textbooks and many clinicians tend to dismiss a 6th nerve palsy, which occurs in the presence of increased intracranial pressure, as having little significance. It has been said that the long intracranial course of the nerve and the fact that it is bound to the pons by the anterior inferior cerebellar artery lend the nerve to easy injury. Were such postulates true, it would seem rather unusual that 6th nerve palsy is not more prevalent and is not more often bilateral. Anatomically, the nerve seems to be well protected against simple increased intracranial pressure, as over half of its course is extradural and outside the subarachnoid space. It is difficult to visualize the resilient artery of a young patient depressing a nerve into the soft brain substance, causing it to lose its function.

In 3 cases of medulloblastoma of the cerebellum, with papilledema, 6th nerve palsy developed in the late postoperative convalescence after the increased presssure had subsided. Indeed, there were 83 case records of children with bilateral papilledema caused by brain tumors (53 infratentorial and 30 supratentorial), none of which had any evidence of involvement of the ocular neuromuscular mechanism.

The production of 6th nerve injury in the pontine and cerebellopontine angle tumors appears clear. The nerve is stretched and flattened as it crosses over the expanding tumor, or it is compressed by the tumor against the basisphenoid. If the pontine tumor is predominantly on one side, then an ipsilateral nerve palsy will result. It should be noted that in these cases increased intracranial pressure tends to occur very late in the tumor develop-

ment while the ocular nerve palsies usually occur early. The nucleus or its fibers may also be directly involved in the pontine substance.

The mechanism in cases of cerebellar tumors is not so clear. However, from the examination of operative and postmortem reports, the following three possibilities are advanced:

1. The large bulky tumor pushes the brain stem forward and compresses the 6th nerve. If the tumor is primarily midline or diffuse, then a bilateral palsy results. However, if one lobe is more involved than the other, then the 6th nerve is affected on the same side although the opposite side may show a mild partial palsy.

2. The tumor has (a) infiltrated the floor of the 4th ventricle, or (b) become adherent to the floor causing tissue reaction. As a result the function of the 6th nerve nucleus is either destroyed by tumor or suppressed by edema. As would be expected the 6th nerve palsy tends to be permanent in these patients. A large proportion of these patients have a 7th nerve involvement because the proximity of the 7th nerve fibers to the 6th nucleus.

3. A combination of the above two factors.

THIRD NERVE PALSIES—TABLE 2

As would be expected in this group, the pontine and mesencephalic tumors account for the majority of the palsies. Of these 7 patients, 3 showed unilateral 3rd nerve signs without evidence of other nerve palsies. The remaining 4 had bilateral 3rd nerve involvement usually combined with 4th and 6th nerve palsies and some supranuclear element.

In the 3 cases of ophthalmoplegic migraine the palsies were, of course, unilateral. The diagnosis was inferred from the episodic nature of the symptoms and signs and the fact that arteriography and air studies were negative. One of these patients 9 years later still has "sick headaches" but no nerve involvement. Another had several episodes prior to admission but was alive and well 5 years later. The third has had many subsequent episodes and has a partial 3rd nerve palsy between attacks.

In both cases of encephalitis the palsies were unilateral with complete recovery.

TABLE 2

Third nerve palsies in children

Etiology	Number of Cases
Pontine and mesencephalic tumors	7
Ophthalmoplegic migraine	3
Encephalitis	2
Cerebral tumor with pressure cone	1
Pituitary	1
Total	14

The cerebral tumor with the pressure cone produced a unilateral 3rd nerve palsy.

It is interesting that in this group of children there should be a case of pituitary tumor, which was large enough to produce pressure on the left 3rd and 4th nerves. One would more readily expect to find a craniopharyngioma, and it is difficult to explain why there is none in this study.

The pathogenesis of the palsies is fairly uniformly agreed upon. The pontine tumor infiltrates the brain stem to produce nuclear, infranuclear, and supranuclear interruptions.

The pressure cone of the hippocampal gyrus over the tentorium is also well understood, and it is thought by some[1] that this also accounts for the mechanism in ophthalmoplegic migraine.

In encephalitis one would infer that the inflammatory reaction involved the brain stem.

SUPRANUCLEAR PALSIES—TABLE 3

These 18 cases fell into two groups. Group 1 consisted of 9 cases in which the eyes showed an almost constant deviation to one side or the other (one of these patients exhibited a constant upward deviation, and another a constant downward deviation) and for the most part the eyes were fixed in this position. In all but one of these cases cortical irritation would be inferred. Meningitis accounted for 5 cases, Sturge-Weber's syndrome for 1, a right subdural abscess and a left subdural hematoma for 2, and in the final case the cause was a tumor lying near the foramen of Monro on the right side.

Group 2 consisted of gaze palsies, usually horizontal. One patient had a loss of convergence, and another had a loss of upward gaze because of a pineal tumor. These palsies were all caused by tumor either of the pons, mesencephalon, frontal neoplasm, infiltrating medulloblastoma, or pineal tumor, as noted. Two of this group were associated with 7th nerve palsy.

In the patients with inferred cortical irritation, the conjugate gaze centers are probably overstimulated, driving the eyes to the opposite side;

TABLE 3

Supranuclear palsies in children

Etiology	Number of Cases
Meningitis	5
Cerebral tumor	4
Pontine tumor	4
Cerebellar tumor	2
Pineal tumor	1
Subdural hematoma	1
Subdural abscess	1
Total	18

whereas, the gaze palsies are undoubtedly caused by an interruption in the nerve pathways below the cortical level.

SEVENTH NERVE PALSIES—TABLE 4

The 2 cases of trauma included 1 case of subdural hematoma, and 1 in which there was an injury to the 7th nerve in a newborn child from application of forceps. The other 2 cases are self-explanatory.

TABLE 4

Seventh nerve palsies in children

Etiology	Number of Cases
Trauma	2
Otitis media	1
Pontine tumor	1
Total	4

MYASTHENIA GRAVIS

Eight cases of myasthenia gravis were noted in the study. There are so many excellent articles on this subject that little need be added here. Six of the cases were characterized by bilateral ptosis and almost complete bilateral external ophthalmoplegia. In 1 case in which the ptosis was predominant, the original diagnosis was a congenital ptosis and the patient had one eyelid operated upon. Six of these 8 patients were Negroes. Incidentally, myasthenia gravis was the only disease encountered in this study that showed a race pattern.

COMMENT

Table 5 represents an accumulation of all the diseases uncovered in this study. These are summarized in Table 6 without any attempt to break down the palsy or the disease process.

It can be seen that intracranial tumors represent approximately 70 per cent of the cases, inflammatory lesions 11 per cent and myasthenia gravis 6 per cent. In 3 per cent of the cases there was no proven etiological factor.

In the absence of evidence of intracranial inflammation, otitis media, trauma or myasthenia gravis, a child with a 6th nerve palsy (unilateral or bilateral and with or without 7th nerve involvement) is a brain tumor suspect. Increased intracranial pressure manifested by choking of the discs should suggest a cerebellar tumor in such a child. Absence of increased intracranial pressure should suggest a tumor of the pons. If, in the latter, there is involvement of the 3rd nerve, the diagnosis of pontine tumor is reasonably certain.

Little has been said about 4th nerve palsy. In this analysis no case of a

TABLE 5

Acquired diseases of the ocular neuromuscular mechanism and seventh nerve palsies in children

Disease	Number of Cases
Pontine tumor	40
Cerebellar tumor	32
Myasthenia gravis	8
Meningitis	7
Cerebral tumor	7
Cerebellopontine angle tumor	5
No etiology discovered	4
Secondary to otitis media	4
Head injury	3
Ophthalmoplegic migraine	3
Encephalitis	2
Direct trauma to nerve or muscle	2
Extradural tumor	1
Pituitary tumor	1
Pineal tumor	1
Subdural abscess	1
Intracranial aneurysm	1
Total	122

patient with a pure 4th nerve palsy was uncovered. In several of the cases there was involvement of the 4th nerve with complete 3rd nerve palsy.

The child with a predominantly 3rd nerve lesion in the absence of encephalitis should be considered as having a pontine or mesencephalic tumor. In cases of episodic 3rd nerve palsy associated with ipsilateral head pain the diagnosis of ophthalmoplegic migraine should be entertained provided air studies and arteriography are negative.

The child who keeps his eyes fixed in relatively one position of gaze should suggest a cortical irritation, in which case meningitis or abscess formation is the most likely possibility. Vascular tumor of the cortex and subdural hematoma should also be considered.

TABLE 6

Summary of Table 5

Etiology	Number of Cases
Intracranial tumor	87
Secondary to inflammatory process	14
Myasthenia gravis	8
Trauma	5
No etiological factor	4
Ophthalmoplegic migraine	3
Intracranial aneurysm	1
Total	122

The final outcome of these 122 cases is summarized in Table 7. Four cases are unaccounted for in the follow-up. In the remaining 118 cases there was a total of 84 deaths, which is slightly more than 70 per cent. Of these deaths, 77 were caused by intracranial tumors, with 1 tumor case unaccounted for. The mortality in this instance is almost 90 per cent. Of the remaining 7 deaths, 5 were from meningitis, 1 from myasthenia gravis and 1 from intracranial aneurysm.

In sharp contrast to the above is the infrequency with which intracranial tumors produce disturbances of ocular motility in the adult. The motor nerves may be involved peripherally by meningiomas of the sphenoidal ridge or by malignant nasopharyngiomas, and occasionally cerebral tumors cause conjugate palsies. However, posterior fossa neoplasms are uncommon in the adult as compared to the child. In the over-all adult picture, tumors account for few cases. This is not the only variance in the differential diagnosis of the adult and child with the same acquired lack of ocular motility.

TABLE 7

Eventual outcome of the 122 patients studied

Present Status	Number of Cases
Dead	84
Alive with normal ocular motility	16
Alive with restricted ocular motility	18
Inadequate follow-up	4
Total	122

Many 6th nerve palsies in the older adult are transitory and the cause is never known. Multiple sclerosis produces many of the disturbances of ocular motility in the younger adult. This disease is rare in children, and when it occurs it selects the optic nerve rather than the motor system. Intracranial aneurysms and extradural hemorrhage probably account for more 3rd nerve palsies in adults than any other disease entities. Arteriosclerosis and/or hypertension with either occlusion or hemorrhage is responsible for many supranuclear and nuclear lesions.

The above is by no means a complete list of the diagnostic possibilities in the adult, however. It does account for approximately 80 to 90 per cent of all interferences with ocular motility in this age group. The child and the adult share in myasthenia gravis and cerebellopontine angle tumors. Migraine and encephalitis may also occur in any age group, but these account for relatively few palsies.

This writer is unaware of any analysis of the mortality in the adult with an acquired lesion affecting the ocular neuromuscular mechanism. In the over-all adult picture it should not be high.

A valid criticism of this analysis might well be the selectivity of the

cases. Doubtless some disease processes which may have caused restriction of ocular motility have been missed. It is felt that these cases would be very few. It is also recognized that this study involves only hospital admissions. There is no way of knowing how many children with transitory palsies affecting either ocular motility or the ability to close the eyelids may have been followed as out-patients.

This survey, therefore, should not in any way be interpreted as a biostatistical analysis. It has revealed, however, a distinct and important over-all pattern to interference with ocular motility in the child and should be considered only from this viewpoint.

SUMMARY

The etiological background of 122 patients under the age of 16 years, with acquired disturbances in the ability to move the eyes or eyelids is presented. The following observations and conclusions are submitted:

1. The generally accepted thesis that 6th nerve palsies are caused by increased intracranial pressure, per se, is challenged. Alternative possibilities concerning the mechanism of production of these paralyses are suggested. Sixth nerve palsies may be of localizing value.

2. Intracranial tumors were present in over 70 per cent of all the children.

3. The over-all mortality rate in the 122 cases is 70 per cent at the time of writing this article. This grave implication of an acquired disturbance in ocular motility makes careful evaluation of every patient mandatory.

4. There is a marked difference in the diagnostic possibilities in the adult as compared to the child with similar impairment of ocular movements.

The compilation of cases for this paper would have been impossible had it not been for the generosity of Dr. Barnes Woodhall of the Duke University Department of Neurosurgery and of the Duke Hospital Medical Records Department in allowing free access to their records.

REFERENCES

1. Harrington, D. O., and Flocks, M. Ophthalmoplegic migraine. A discussion of its pathogenesis with a report of the pathologic findings in a case of recurrent oculomotor palsy. *Trans. Amer. Acad. Ophthal. Oto-laryng.*, 1953, *57*: 517–528.

2. Murray, R. G., and Walsh, F. B. Ocular abnormalities in poliomyelitis and their pathogenesis. *Canad. med. Ass. J.*, 1954, *70*: 141–147.

CASE REPORTS

OSTEOCLASTOMA OF THE SKULL

B. RAMAMURTHI, F.R.C.S.,* G. S. VISVANATHAN, M.D.,† AND
K. M. PILLAI, M.B.‡
Madras, India

(Received for publication November 22, 1954)

Osteoclastoma of the skull is a rare condition. Only 10 cases have been reported in the available literature. Coley[1] said that this variety of bone tumour is exceedingly rare in the bones of the skull and believed it probable that such cases as have been described may actually have been examples of fibrous dysplasia with giant cells present in the periphery of the lesion. Geschickter and Copeland[3] found 4 giant-cell tumours in their collection of 52 tumours of the skull. Two of these tumours arose in the temporal fossa from the sphenoid bone, 1 occurred in the mastoid region and 1 in the occipital bone. They referred to 2 cases reported previously, one by Troell[8] and the other by Fraser.[2] In Fraser's case the tumour developed in the left half of the frontal bone in a man aged 42 and was removed after deep X-ray therapy. They felt that the lesion in this case may have been a diploic haematoma with osteoclast formation and not a true giant-cell tumour.

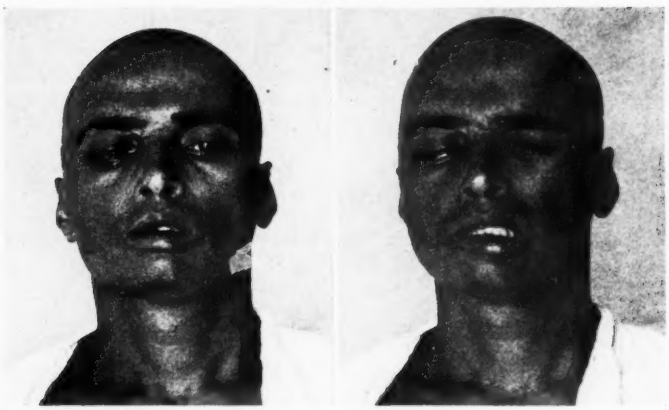
Lord and Stewart[5] and Shrivastav and Sharma[7] have described osteoclastomas arising in the temporal bone, but projecting through the external auditory meatus. Rowbotham[6] reported a case of osteoclastoma of the temporal bone causing a swelling in the temporal region and progressing slowly. Govinda Reddy[4] in an analysis of 460 bone tumours, from the Department of Pathology, Madras Medical College, found 96 giant-cell tumours, none of which arose from the bones of the calvarium.

Giant-cell formation is seen during the normal process of bone absorption in intracartilaginous bones and hence giant-cell tumours are found in association with bones derived from cartilage. In the cases reported above the tumours arose from the regions of the calvarium derived from cartilage. Rare are giant-cell tumours of the skull and rarer still are tumours that grow intracranially and simulate other tumours. The following case merits recording because of its rarity and also because of its interesting features, the patient presenting the clinical signs of an intracranial tumour simulating a pituitary tumour.

CASE REPORT

NS 3120. G., a male aged 35 years, was admitted on March 3, 1954 with a complaint of headache and gradually increasing dimness of vision. His illness began 5 months previously with periodic attacks of headache, starting in the occipital region and spreading forwards. Then the patient found that he was not able to see properly with the right eye. For the last month, he had not been able to lift his right eyelid (Fig. 1).

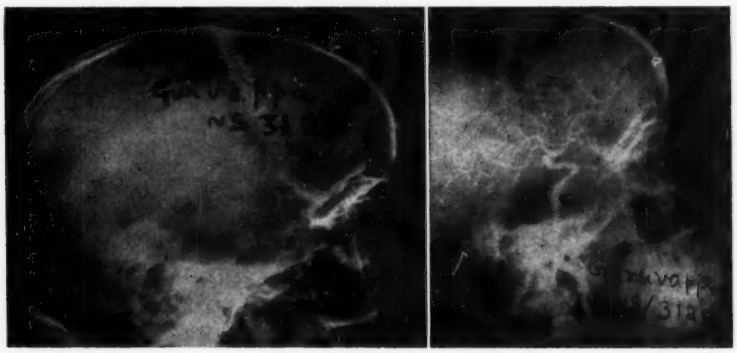
* Neurosurgeon, General Hospital, Madras.
† Professor of Pathology, Madras Medical College.
‡ Radiologist, Bernard Institute of Radiology, General Hospital, Madras.



FIGS. 1 and 2. Photographs of patient showing (*left*) 3rd nerve paralysis, and (*right*) right lower motor facial paralysis.

Examination. He was a fairly well nourished individual in good general health. Positive neurological findings were: (i) primary optic atrophy on the right and temporal pallor of the left optic disc; (ii) complete loss of vision in the right eye, with contraction of temporal field in the left eye; (iii) limitation of medial and upward movements in the right eye, whereas external rotation of the eye was not limited; and (iv) ptosis of the right eyelid. The patient also had a lower motor paresis of the right facial nerve (Fig. 2).

A clinical diagnosis of pituitary tumour with extrasellar extension to the right side was made, but it was difficult to explain the right facial palsy. Roentgenograms of the skull showed enlargement and erosion of the pituitary fossa (Fig. 3). Cerebral angiography excluded an aneurysm and showed the internal carotid artery lifted upwards and backwards and laterally by a tumour in the pituitary region (Fig. 4). Surgery was advised but the patient refused and went home.



FIGS. 3 and 4. (*Left*) Roentgenogram of skull showing enlargement and erosion of pituitary fossa. (*Right*) Angiogram showing internal carotid artery lifted upwards and backwards by the tumour in the pituitary region.

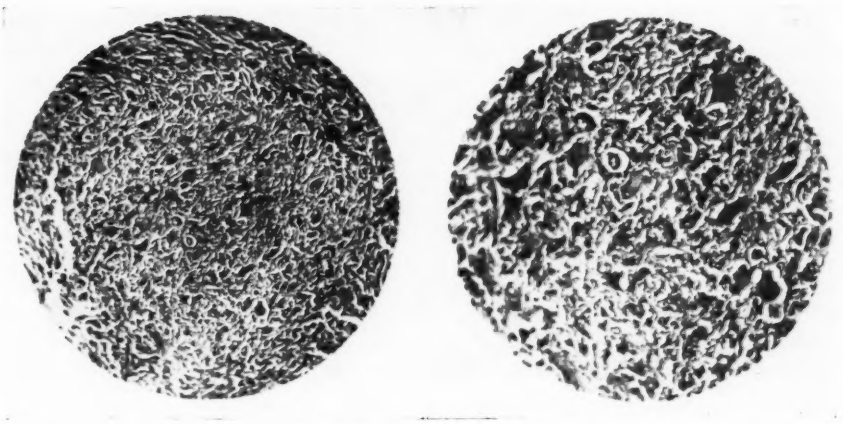


FIG. 5. Microphotographs showing (*Left*) giant-cell tumour (×160) and (*right*) giant cells and spindle cells (×320).

Course. When he reported 6 weeks later, all the previous signs had advanced; in addition a certain amount of obstruction of the right nose had developed. The nasopharynx was examined and it was thought probable that the obstruction in the nose was caused by extension of the intracranial growth into the nasopharynx. The patient agreed to undergo surgery.

Operation. Under endotracheal general anaesthesia (induction with intravenous pentothal and curare) a right frontal osteoplastic flap was raised. A purplish discolouration was found under the dura mater over the frontal pole and the undersurface of the frontal lobe. On incising the dura mater, it was found to be a subdural cyst, containing old blood. After this was evacuated, it was possible to retract the frontal lobe backwards and the optic nerves and the chiasma could be seen. There was a tumour which was pushing itself between the two optic nerves and pushing the optic chiasma backwards (site of a classical adenoma of the pituitary). The tumour also extended on the lateral aspect of the right optic nerve. The capsule was incised and as much of the tumour as possible was removed by punching and suction. It was felt to be firmer than the usual adenomas of the pituitary. The dura mater was closed and the wound was closed in layers.

Pathological Report. The diagnosis of the tumour was osteoclastoma (Fig. 5).

Course. After the operation the patient had relief from headache. Additional roentgenograms were taken and those of the base of the skull showed destruction of the right half of the base (Fig. 6).

A month later, the patient reported that he had no improvement either in vision or in the ptosis. In addition, anaesthesia was found to be developing over the right half of the face. The patient was advised to have deep X-ray therapy, which he refused.

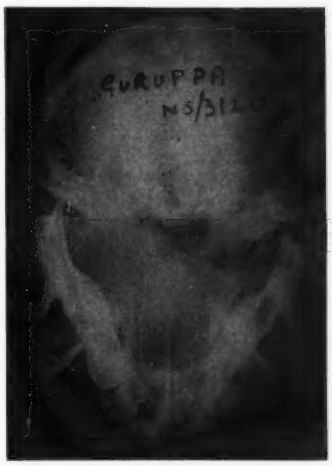


FIG. 6. Roentgenogram of base of skull showing destruction of the right half of the base.

DISCUSSION

The tumour was primarily thought of as a pituitary adenoma because of the presenting symptoms, although the facial paralysis could not be explained by this diagnosis. The firmness of the tumour, the facial paralysis, and the radiological appearances, all fitted in with the diagnosis of osteoclastoma. The appearance of the base of the skull showing erosion of the bone confirms the observation made by Geschickter and Copeland that radiologically, giant-cell tumours of the skull bones show sharply demarcated areas of bone destruction and not the typical soap-bubble appearance that is seen in the long bones.

SUMMARY

A case is reported of osteoclastoma of the sphenoid bone simulating a pituitary tumour. Osteoclastoma of the skull bones is a rare condition. The case also presented many interesting features that are discussed.

We wish to express our thanks to The Dean, Madras Medical College and General Hospital, Madras, for permission to publish this paper.

REFERENCES

1. Coley, B. L. Neoplasms of bone and related conditions. Their etiology, pathogenesis, diagnosis, and treatment. *New York: P. B. Hoeber, Inc.*, 1949, xiv, 765 pp. (see p. 423).
2. Fraser, J. Cited by Geschickter and Copeland.[3]
3. Geschickter, C. F., and Copeland, M. M. Tumors of bone. *Philadelphia & London: J. B. Lippincott Co.*, 1949, 3rd ed., xviii, 810 pp. (see pp. 629–641).
4. Govinda Reddy, D. Giant-cell tumour with a brief survey of bone tumours examined in the Department of Pathology, Madras Medical College, Madras. *Indian J. Surg.*, 1953, *15:* 37–42.
5. Lord, O. C., and Stewart, M. J. Osteoclastoma of the temporal bone. *J. Laryng.*, 1943, *58:* 263–271.
6. Rowbotham, G. F. An osteoclastoma of the skull. *Brit. J. Surg.*, 1952, *39:* 527–529.
7. Shrivastav, J. B., and Sharma, K. D. Osteoclastoma from the temporal bone. *Indian J. Surg.*, 1954, *16:* 100–101.
8. Troell, A. Cited by Geschickter and Copeland.[3]

CEREBRAL GRANULOMA CAUSED BY SCHISTOSOMA JAPONICUM

TAKAO MITSUNO, M.D.

Second Surgical Clinic, Kyushu University School of Medicine, Fukuoka, Japan

(Received for publication November 29, 1954)

While infestation with Schistosoma japonicum occurs very frequently in Japan, cerebral schistosomiasis caused by this species is extremely rare. The first report of cerebral schistosomiasis in the literature, as far as is known, was an autopsy report by Yamagiwa[28] in 1889. The second was an autopsy report by Shimamura and Tsunoda[22] in 1905. Shimidzu,[23] in 1935, apparently was the first to describe a case in which the lesion was verified by operation. Subsequently other reports of surgically verified cases were published.[2–4,8,9,15,20,21,24,25,27] Kato and Ootsuka[13] in 1950 operated on a patient in Japan who had been infected in China. Although many cases of cerebral schistosomiasis broke out among American troops after their landing on Leyte in the Philippines in October, 1944, this disease is still quite rare.

Following is an additional report of a case in which operation was performed.

CASE REPORT

T.K., a boy aged 19, student of senior high school, was admitted to our clinic on Nov. 4, 1952 complaining of severe headaches, visual disturbance and epileptic seizures. Since May 1952 he had suffered from general malaise and cold sweats. On June 30 a convulsive seizure occurred for the first time. Early in July 1952 he began to complain of headaches and a feeling of heaviness in his head. He said that he felt as if he had a ball inside his cranium and that the location of his headaches changed as he changed the position of his head. His symptoms progressed and he complained of dizziness, nausea, vomiting and sleeplessness since the middle of August and of visual disturbance since the beginning of September. He had noticed a slight defect in speech (stammer) since the middle of October. On October 22 he had his second convulsive seizure, beginning with his right hand and spreading to his whole body, with loss of consciousness and with his face rotated to his right side. For several days before admission he had complained of tinnitus and of something fluttering in front of his eyes.

Past History. He was born and has lived in Kyushu Island, Japan (near the endemic area of schistosomiasis), except between the ages of 5 to 11 years when he resided in Mukuden, Manchuria.

He suffered from dysentery at 4 years of age. He was told that his liver was enlarged at the age of 14. However, he has had no other symptoms that occur in schistosomiasis.

Examination. Papilledema was present and visual acuity bilaterally was limited to perception of hand movements. "Knock-pain" and Macewen's sign were present in the left parietotemporal region. There was hypoesthesia with slight weakness and increased tendon reflexes of the left hand and leg. He had great difficulty in writing and frequently wrote the wrong letters. He also showed slight astereognosis.

Laboratory Findings. The hemogram showed 5,210,000 RBC, 81 per cent hb. and 6,000 WBC with 58 per cent neutrophiles, of which 54 per cent were segmented, 32 per cent lymphocytes, 4 per cent monocytes and 6 per cent eosinophiles. The urine was normal. The stools were brown, formed, and were positive for ova of Ascaris but negative for ova of Schistosoma japonicum (in spite of several examinations of the stools after verification of the diagnosis). They were also negative for occult blood. BP was 108–70 mm. of mercury. Sedimentation rate of blood was 47 mm. for 1 hour, and 83 mm. for 2 hours. Syphilitic reaction of serum was negative. Circulating blood volume was 6375 cc. (115.8 cc./kg.); circulating plasma volume,

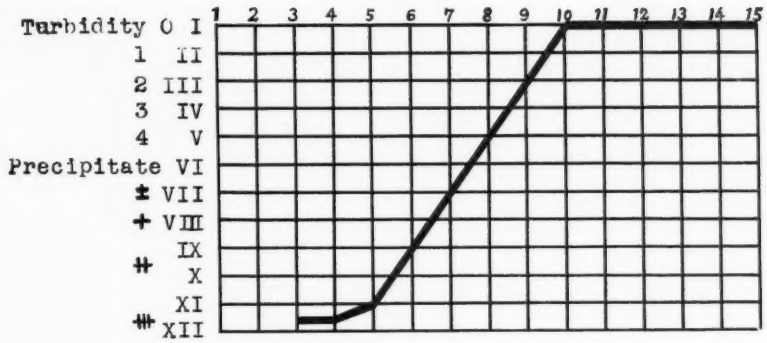


FIG. 1. Graph showing curve of mastic reaction.

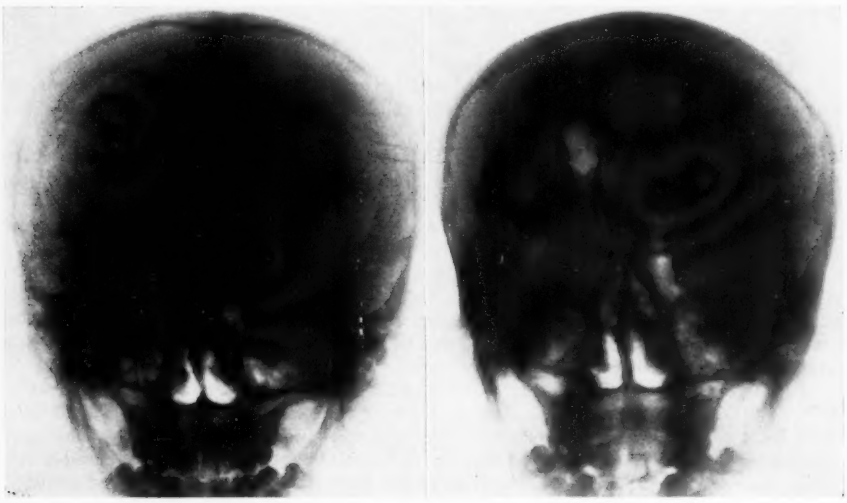
3187 cc. (57.8 cc./kg.); protein contents in serum 8.7 gm./deciliter; and value of hematocrit 50 per cent.

The CSF pressure was 850 mm. of water. The fluid was grossly clear, and showed the following syphilitic reactions: Nonne-Apelt 3+, Weichbrodt 3+, Wassermann 2+, and mastic test showed the curve of progressive paralysis (Fig. 1).

EEG revealed irregular waves over the whole scalp, most marked in the left parietal region. Pneumoencephalogram showed that the lateral ventricles were shifted markedly from left to right. There was depression of both the frontal and occipital poles of the left lateral ventricle (Figs. 2 and 3).

A diagnosis of left parietotemporal tumor was made.

Operation. On Nov. 18, 1952, osteoplastic craniotomy was carried out. The dura mater was very tense but was found neither thickened nor adherent on incision. Two grayish-white firm tumor masses, the size of a sparrow's egg, underlying the left parietal cortex were



FIGS. 2 and 3. Roentgenograms showing depression of frontal and occipital poles of left lateral ventricle.

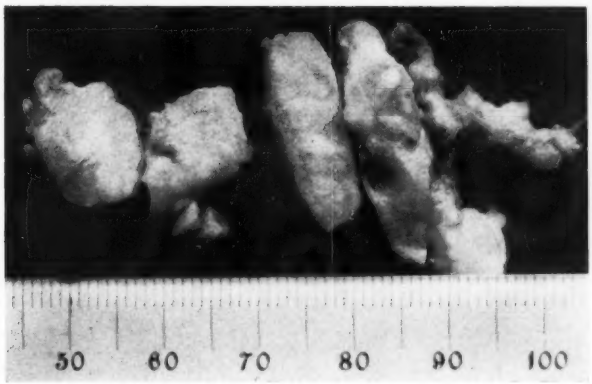


FIG. 4. Photograph of sections of two cerebral granulomas removed at operation. Note the several miliary spots (miliary abscesses).

removed. These tumor masses could easily be stripped from the surrounding brain parenchyma. No tumor was found by exploratory puncture in other parts of the brain.

Postoperatively the patient's cerebral symptoms improved, although he has had no recovery of visual power. He was last seen on Jan. 30, 1953, when he reported for follow-up examination.

Pathological Report. Sections of the tumor masses revealed several yellowish, miliary spots (Fig. 4) with a necrotic zone (Fig. 5), as is usually seen in an abscess. Except for these small spots, the tumor mass was greyish-white, and appeared quite avascular. The microscopic diagnosis (Figs. 6–10) was granulomas of the brain containing ova of Schistosoma japonicum (Prof. I. Miyazaki, Department of Parasitology, Kyushu University School of Medicine).

DISCUSSION

Cerebral schistosomiasis caused by Schistosoma japonicum was brought to the attention of the medical profession particularly after the landing of American troops

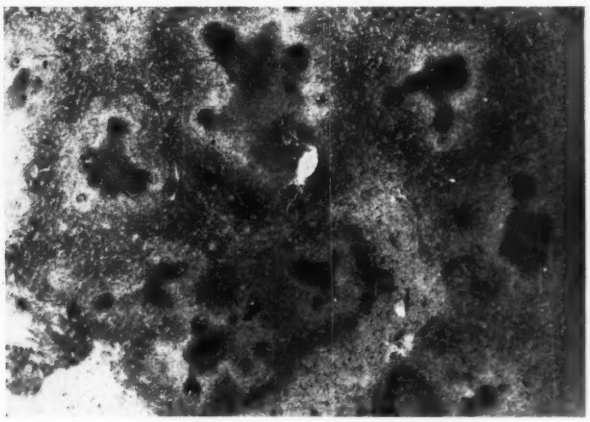


FIG. 5. Photomicrograph of miliary abscesses, showing a focal granulomatous lesion. (Hematoxylin and eosin stain, ×13)

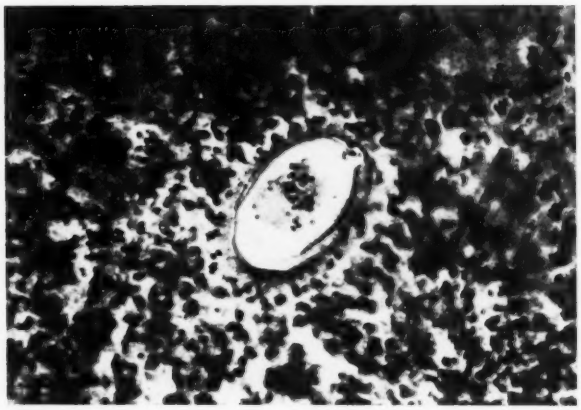


FIG. 6. Ovum of Schistosoma japonicum lying in a central necrotic zone. (Hematoxylin and eosin stain, ×320)

on the Philippines in October 1944. It has been described in detail by Faust,[6,7] Kane and Most,[12] and Carmichael and Cowley,[2] and no attempt will be made to recount this here. It is said that the first report of cerebral schistosomiasis was made by Yamagiwa[28] in 1889. Since then 4 additional autopsy cases have been published. The first to describe a surgically verified case was Shimidzu[23] in 1935. In reviewing the literature since then the writer has found 21 additional cases in which the lesion was verified by operation, including the case presented here. In all these 27 cases the ova of Schistosoma japonicum were found in the brain at surgical operation or at autopsy. The known geographical locations of these cases were as follows: 18 patients were infected in the Philippines, all of them after 1944; 4 in China; and 4

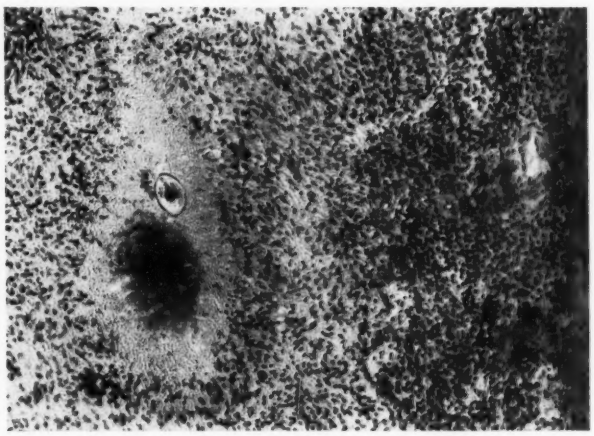


FIG. 7. Photomicrograph of the granuloma, showing an egg and 3 layers: central necrotic zone, middle zone of epithelioid cells, and cellular layer. (Hematoxylin and eosin stain, ×90)

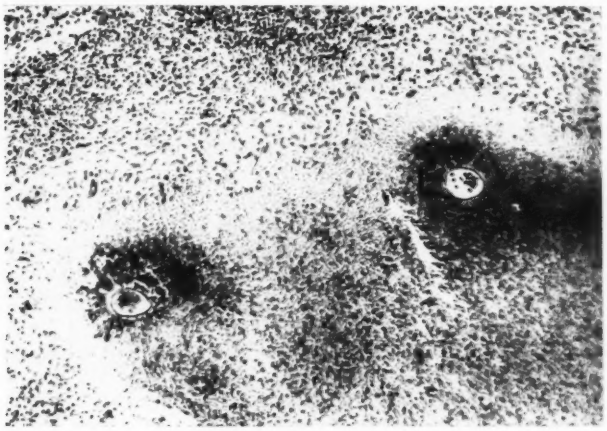


FIG. 8. Showing two necrotic zones in the granuloma, with 2 eggs and inflammatory reaction around them. (Hematoxylin and eosin stain, ×85)

in Japan. Of the 27 cases, 7 were reported before 1944 and 20 after 1944. The large number of cases after 1944 followed the military operation of American troops in the Philippines.

In Japan schistosomiasis japonica is called "Katayama disease" (Katayama is the name of an endemic locality of schistosomiasis japonica in the Hiroshima Prefecture, Japan). The disease was studied extensively by the Japanese and much of our present knowledge about it was reported by them. In 1904 Katsurada[14] discovered the etiological agent and named it Schistosoma japonicum. In 1913 Miyairi and Suzuki[17] discovered a new species of small water snail, Oncomelania nosophora, to be the intermediary host of the disease. Schistosoma japonicum is

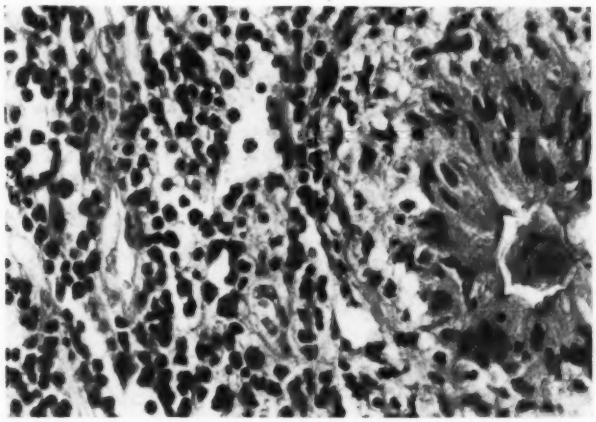


FIG. 9. Higher magnification (×320) of a cellular layer, showing a giant cell around an egg. (Hematoxylin and eosin stain)

chiefly distributed in Yamanashi Prefecture; Katayama province in Hiroshima Prefecture; near Numazu in Shizuoka Prefecture; the area watered by the Tone River; and in Kyushu, the area watered by the Chikugo River. Okabe[19] presumes that there are at least 10,000 people with schistosomiasis japonica in the endemic area watered by the Chikugo River, for approximately 10 per cent of the inhabitants of this area are estimated to harbor the eggs of Schistosoma japonicum as determined by streak examinations of the stools. It is thought that in all of Japan the number of people infected with schistosomiasis japonica runs into hundreds of thousands. However, reported cases of invasion of the central nervous system, infected in Japan, are only 4, including my own case. The writer knows of only 9 cases of cerebral invasion in Japan, including 5 presumptive cases of schistosomiasis japonica complicated by jacksonian seizures, reported by Motoyama.[18] (Abstracts

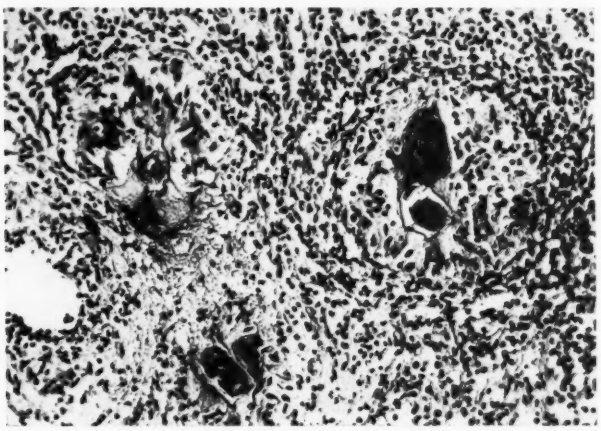


FIG. 10. Three giant cells, each of which surrounds an egg. (Hematoxylin and eosin stain, ×156)

of his cases will be given in an appendix at the end of this article, for Motoyama's report may not be known to many readers.)

It is of interest that Africa and Santa Cruz[1] reported that ova of Schistosoma japonicum were found in the brain of an individual who had no history of neurological symptoms. The eggs in this case were more abundant in the heart.

I can say that the ratio of cerebral schistosomiasis to schistosomiasis in Japan is extremely small. The experience among natives of the Philippines is similar to that in Japan. It is supposed that many natives suffer from schistosomiasis japonica, but concerning the number of cerebral infections Chang *et al.*[3] said: "In the Philippine medical literature there are only two reports before Vitug's (1941) referring to schistosomiasis of the brain."

On the contrary, relatively many among American troops have suffered from cerebral schistosomiasis since they landed on the Philippines. Kane and Most[12] reported that there were 27 known cases with a clinical diagnosis of schistosomiasis involving the central nervous system which occurred among the military personnel since October 1944, and that these constituted approximately 2.3 per cent of all known cases (1,200) of schistosomiasis japonica contracted during the Leyte campaign. Moreover, according to the report of Egan,[5] 12 out of 18 English sailors

who went swimming in the Yangtze River in China subsequently exhibited characteristic clinical symptoms of schistosomiasis japonica. Two of the 12 presented signs of severe involvement of the central nervous system. Edgar[4] and Greenfield and Pritchard[8] each reported 1 operative case of cerebral schistosomiasis japonica in English Naval officers stationed in China.

Apparently the ratio of invasion of the central nervous system in schistosomiasis japonica is relatively large among the English and Americans, but quite small among the natives of Japan and the Philippines. It has been said that acute symptoms of schistosomiasis japonica are rarely seen in individuals who inhabit the endemic areas, but occur frequently in patients strange to these areas. Many cases of acute schistosomiasis japonica broke out after a flood in the area watered by the Chikugo River, Kyushu, in June, 1953. The reason for this difference in incidence of cerebral involvement is obscure. In the case of the American troops in the Philippines, their abnormal circumstances (overwork, sleeplessness and so on) may have been contributing factors. However, this does not seem to be enough to explain the whole picture. There are two other possibilities; first, the natives may have acquired immunity against cerebral infection by Schistosoma japonicum, and secondly there may be a racial difference between Orientals and Occidentals.

Many authors consider that the best description of the microscopic appearance of cerebral granuloma caused by Schistosoma japonicum is that given by Shimidzu.[23] He divided the granuloma into three layers: (a) a central zone of necrosis, (b) a middle zone of epithelioid cells and (c) a cellular layer composed of lymphocytes, plasma cells, eosinophiles, fibroblasts and an abundant lattice of fibrils. These microscopic changes were observed in my case too (Figs. 7 and 8), and a number of ova of Schistosoma japonicum may be recognized in the central necrotic zone and middle zone (Figs. 6, 7 and 8). Some parts of a cellular layer consist of lymphocytes almost totally, and other parts contain many plasma cells. There is an area in which there are many multinuclear foreign body giant cells, some of which surround ova (Figs. 9 and 10).

The route of invasion by ova of Schistosoma japonicum has interested many authors. Generally speaking there are two theories concerning the route: (1) Direct deposition: the worm reaches the cerebral circulation by chance and directly deposits the eggs there.[8,12,23] (2) Indirect (or embolic) deposition: the eggs enter the general circulation and lodge in the brain. There is little supportive evidence for these two theories, but the thought of embolic deposition of eggs may be correct in cases of diffuse dissemination.[2,10,22,26,28,29] I believe that in my case it is more reasonable to suppose that there was direct deposition of worms near the site of the granulomas, than to think of embolic deposition, for there were two granulomas in a relatively small area.

The disease cannot be diagnosed definitely unless the ova of Schistosoma japonicum or the worms are recognized in the brain at operation or autopsy, or in the cerebrospinal fluid. Carmichael and Cowley[2] reported a case in which ventricular fluid contained free floating ova of Schistosoma japonicum, but such a case is rare and, as far as I know, there are no cases in which ova have been shown in the cerebrospinal fluid preoperatively. There are many signs that aid in the diagnosis: (a) history of symptoms of schistosomiasis japonica, (b) verification of the eggs in the stools, (c) eosinophilia in the blood, and (d) recognition or increase of eosinophiles in the cerebrospinal fluid, which usually indicates parasitic infection of the central nervous system. In cerebral schistosomiasis the mastic reaction of the

cerebrospinal fluid may be paretic in type, just as it was in all of my cases of cerebral paragonimiasis previously reported,[16] or it may be meningitic, as reported by Ikebukuro.[11]

SUMMARY AND CONCLUSION

A surgical case of cerebral schistosomiasis japonica is reported. Although the incidence of schistosomiasis is very high in Japan, as well as in the Philippines, the known instances of cerebral infections are very rare among the natives. The author therefore believes that cerebral infection is a very rare complication among the natives in the endemic areas. On the other hand, American troops in the Philippines and English Navy personnel in China suffered from cerebral infection in a relatively high percentage of cases. This brings up the question as to whether or not the natives in the endemic areas may have acquired an immunity against the cerebral manifestations of schistosomiasis japonica. Finally, there may be a racial difference.

APPENDIX

The following cases have been abstracted from Motoyama's report:[18]

Case 1. A man, aged 20, had felt occasional dizziness since 1932. Jacksonian seizures ensued on April 16 and 23, 1935. After that he complained of severe headaches, occasional dizziness, and malaise of the left hand. Eggs of Schistosoma japonicum were recognized in the stools on June 30, 1935. Stibunal (antimony and sodium tartrate) was injected intravenously with doses of 20, 25 and 30 cc. on alternate days. The patient began to get better after about 7 injections, and recovered satisfactorily after 15 injections.

Case 2. A man, aged 20, suffered from attacks of dizziness and unconsciousness in May, 1933. In the summer of 1935 he had attacks of headache, dizziness and unconsciousness. On May 28, 1936 he suffered an attack which began with headache, dizziness and a feeling of darkness in front of the eyes and proceeded on to unconsciousness and a generalized tonic convulsion. Examination of the stools showed many ova of Schistosoma japonicum and Ascaris. In spite of the treatment of Ascaris there were two more convulsive attacks with dizziness and headaches which continued until the end of July. The intravenous injection of Stibunal was started in early August. The cerebral symptoms disappeared entirely after 18 injections of Stibunal.

Case 3. A woman, aged 25, since April 1935 had had severe headaches which had continued with sudden onset of dizziness. Many eggs of Ascaris and Schistosoma japonicum were recognized in the stools on Aug. 26, 1936. Cerebral symptoms disappeared after 15 injections of Stibunal.

Case 4. A man, aged 38, had complained of headache, dizziness, and high fever (101.5°F.). His temperature decreased in about a week, but during and after this period he had occasionally suffered from attacks of unconsciousness and falling down following dizziness. Eggs of Schistosoma japonicum were recognized in the stools on Oct. 9, 1936. Cerebral symptoms disappeared after approximately 15 injections of Stibunal.

Case 5. A man, aged 46, had been kept to his bed with a sudden attack of headache and dizziness on Oct. 11, 1936. He could not eat or drink anything because of persistent vomiting on the night of Oct. 30, 1936. Many eggs of Schistosoma japonicum and a few eggs of Trichocephalus trichiura were recognized in the stools. Cerebral symptoms disappeared after 15 injections of Stibunal.

All these 5 patients have lived in the endemic areas of Schistosoma japonicum or in the neighborhood thereof, Yamanashi Prefecture, Honshu, Japan. There were no recurrences of symptoms 1 or 2 years after recovery with injection of Stibunal.

REFERENCES

1. Africa, C. M., and Santa Cruz, J. Z. Eggs of Schistosoma japonicum in the human heart. In: *Volumen Jubilare por Prof. Sadao Yoshida.* Osaka, Japan: 1939, *2:* 113–117. (Cited by Kane and Most[12]).
2. Carmichael, F. A., Jr., and Cowley, H. S. Schistosomiasis of the brain. *J. Neurosurg.*, 1952, *9:* 620–634.
3. Chang, T.-H., Smith, G. W., Riesenman, F. R., and Alston, E. F. Cerebral granuloma due to schistosomiasis. *J. Amer. med. Ass.*, 1948, *136:* 230–238.
4. Edgar, W. H. Report on a case of epilepsy due to infection by the Schistosomum japonicum. *J. roy. nav. med. Serv.*, 1936, *22:* 150–153. (Cited by Kane and Most.[12])
5. Egan, C. H. An outbreak of schistosomiasis japonicum. *J. roy. nav. med. Serv.*, 1936, *22:* 6–18. (Cited by Kane and Most.[12])
6. Faust, E. C. Schistosomiasis japonica: its clinical development and recognition. *Ann. intern. Med.*, 1946, *25:* 585–600.
7. Faust, E. C. An inquiry into the ectopic lesions in schistosomiasis. *Amer. J. trop. Med.*, 1948, *28:* 175–199.
8. Greenfield, J. G., and Pritchard, B. Cerebral infection with *Schistosoma japonicum. Brain*, 1937, *60:* 361–372.
9. Hanbery, J. W. Cerebral schistosomiasis japonica. A case report. *Stanford med. Bull.*, 1948, *6:* 382–387. (Cited by Carmichael and Cowley[2])
10. Hunt, W. E., Abramson, W., and Weaver, T. A., Jr. Cerebral schistosomiasis. Report of a case simulating cerebral neoplasm. *J. Amer. med. Ass.*, 1948, *136:* 686–689.
11. Ikebukuro, H. [A case of paragonimiasis.] *Rinsho Shonika Zasshi* [J. clin. Pediat.], 1933, *7:* 925–940. (Japanese.)
12. Kane, C. A., and Most, H. Schistosomiasis of the central nervous system. Experiences in World War II and a review of the literature. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 141–183.
13. Kato, A., and Ootsuka, Y. [A case of jacksonian epilepsy caused by invasion of the cerebral cortex by Schistosomum japonicum ova.] *Geka-no-Ryoiki* [Section of Surgery], 1953, *1:* 546–550. (Japanese)
14. Katsurada, F. Schistosomum japonicum, ein neuer menschlicher Parasit, durch welchen eine endemische Krankheit in verschiedenen Gegenden Japans verursacht wird. *Annot. zool. jap.*, 1904, *5:* 147–160.
15. Maltby, G. L., and Schmidt, J. R. Cited by Kane and Most.[12]
16. Mitsuno, T., Takeya-Sikô, Inanaga, K., and Zimmerman, L. E. Cerebral paragonimiasis. A neurosurgical problem in the Far East. *J. nerv. ment. Dis.*, 1952, *116:* 685–714.
17. Miyairi, K., and Suzuki, M. [The growth of Schistosomum japonicum.] *Tokyo Iji Shinshi* [Tokyo med. J.], 1913, *no. 1836:* 1–5. (Japanese)
18. Motoyama, T. [Cured cases of schistosomiasis japonica complicated by symptoms simulating jacksonian seizures.] *Nippon Iji Shuho* [Japanese med. Wkly.], 1938, *44:* 440–442. (Japanese)
19. Okabe, H. [Schistosomiasis japonica in the area watered by the Chikugo River.] *Rinsho to Kenkyu* [Clinics and Research], 1954, *31:* 430–435. (Japanese)
20. Perkins, R. F., and Uihlein, A. Cerebral schistosomiasis. A report of one proven and two presumptive cases. *J. nerv. ment. Dis.*, 1948, *107:* 207–219.
21. Reeves, D. L., and Kerr, R. W. Schistosomiasis japonica with intracerebral granuloma; operative removal with recovery. Report of a case. *Arch. Neurol. Psychiat., Chicago*, 1947, *58:* 207–220.
22. Shimamura, S., and Tsunoda, T. [Pathology of so-called Katayama disease. Supplementary report on the cause of jacksonian epilepsy and embolism of the cerebral artery.] *Kyoto Igaku Zasshi* [J. Kyoto med. Ass.], 1905, *2:* 149–175. (Japanese)
23. Shimidzu, K. Ein Operationsfall von Schistosomiasis cerebri. *Arch. klin. Chir.*, 1935, *182:* 401–407.
24. Speigel, I. J. Cerebral schistosomiasis. Report of a case with surgical removal of an intracerebral mass of schistosomal ova. *J. Neurosurg.*, 1947, *4:* 72–80.
25. Swanson, H. S. Cerebral granuloma due to schistosomiasis japonica. *J. Neurosurg.*, 1946, *3:* 538–542.
26. Vitug, W., Cruz, J. R., and Bautista, L. D. Schistosomiasis involving the brain. Two case reports. *J. Philippine Islands med. Ass.*, 1941, *21:* 291–298. (Cited by Kane and Most.[12])
27. Watson, C. W., Murphey, F., and Little, S. C. Schistosomiasis of the brain due to Schistosoma japonicum. Report of a case. *Arch. Neurol. Psychiat., Chicago*, 1947, *57:* 199–210.
28. Yamagiwa, K. [Contribution to the etiology of jacksonian epilepsy. Pathological changes of the cerebral cortex caused by Distoma eggs.] *Tokyo Igakkai Zasshi* [J. Tokyo med. Ass.], 1889, *3:* 1032–1042 .(Japanese)
29. Yamagiwa, K. Beitrag zur Aetiologie der Jackson'schen Epilepsie. *Virchows Arch.*, 1890, *119:* 447–460.

DIASTEMATOMYELIA ASSOCIATED WITH DORSAL KYPHOSIS PRODUCING PARAPLEGIA

WILLIAM D. SHOREY, M.D.*
American University Hospital, Beirut, Lebanon

(Received for publication December 14, 1954)

In the course of the last two decades scattered reports have appeared in the literature regarding the two separate conditions of diastematomyelia and kyphoscoliosis with paraplegia. In all, 62 cases of diastematomyelia were found in the literature.[2–4,6–13] A review of the reports of kyphoscoliosis with marked neurological symptoms revealed a total of 43 well-proven cases.[5,9] As far as is known this is the first case to be reported in which the two conditions existed in the same patient. It is presented as an unusual entity and it may suggest a possible reason for the development of neurological symptoms in some cases of kyphoscoliosis. The co-existence of two lesions in the bony spinal column and the presence of a single neurological abnormality are of interest in the problem of the etiology of diastematomyelia.

CASE REPORT

#75293 A.U.H. M.M., aged 12, was referred with the complaint of gradual paresis of both lower legs of 7 months' duration. With the exception of kyphosis and possibly scoliosis, which had been noticed at birth, the patient's early development was allegedly normal. He walked at the age of 18 months. There was a history of consanguinity at the level of his great-grandparents. There was no history or evidence of tuberculosis in his family.

The patient had been well and able to work on his father's land until 7 months before admission. At that time his family noticed that his gait had become unsteady and that he was beginning to stumble. This progressed rather quickly, so that within 1 month he was unable to walk without support. Two months after the onset of his symptoms he was taken to a hospital and put on a hard bed for 2 months. This produced no improvement. He was then put in a plaster cast to include all of both legs and back for 3 months. When the cast was removed, the patient found that he could not move his legs at all and that his legs had become numb. He was then brought to the American University Hospital in Beirut.

Examination. He was a well-built, well-nourished boy in no distress. At T6 there was a marked kyphosis with slight left scoliosis (Fig. 1). Over the spine at the level of L1 to L3 there was an area of pigmentation and a prominent tuft of hair (Fig. 2).

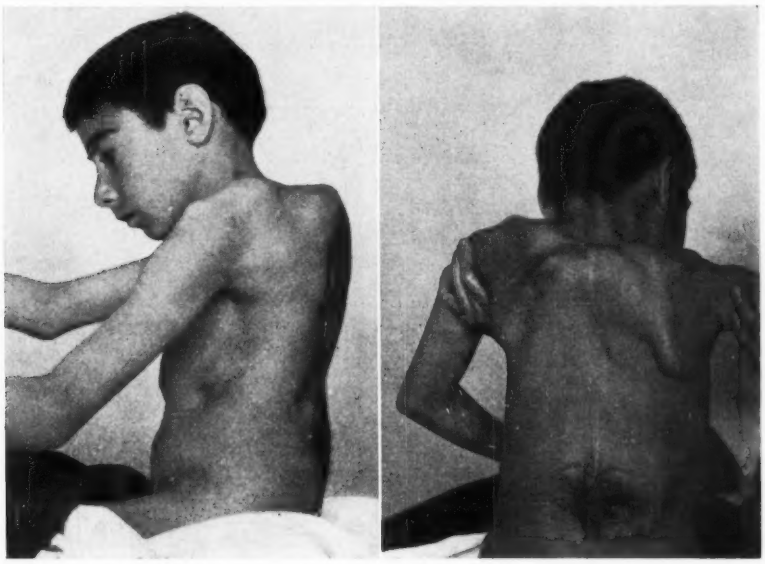
Neurological examination revealed a level of hypaesthesia at T10, and a loss of light touch sensation at T6. Deep touch sensation was slightly decreased from T6 to L1, moderately decreased from L1 to L3 and was absent below L4. Position and vibratory sensations were lost below T10. There was spastic paralysis of both lower legs. Abdominal reflexes were absent. Knee and ankle jerks were markedly increased with prolonged clonus at both ankles. Babinski and Gordon reflexes were positive. There was no abnormality of sphincter control. There was no difference in the size or length of the legs.

The clinical impression was compression of the cord at T6 with fixation of the cord, probably by a meningomyelocele between L2 and L3. Roentgenograms revealed that there was a sharp angulation of the thoracic spine to about 90° at the level of T6 to T7. T6 was shown to be a posterior hemivertebra wedged in between the two contiguous vertebrae, but

* Now at 5 South Wabash Avenue, Chicago, Illinois.

markedly shifted dorsally. In the upper dorsal spine there was furthermore a moderate left concave scoliosis. All the lumbar vertebrae showed an extensive schisis of their arches; L3 and L4 showed schisis of the body as well. No spinal process of the lumbar vertebrae was seen in the frontal views except for L2 which showed an oblong ring-like shadow which had the general appearance of the cross section of spinous process. The disc space between L2 and L3 was markedly narrowed.

A myelogram was performed which revealed a complete block of the column of dye at the level of the sharp angulation in the upper thoracic spine (Fig. 3). The spinal canal in the lumbar spine was uniformly wider than normal. At the level of L2 the spinal canal showed a



FIGS. 1 and 2. (*Left*) Profile photograph showing marked kyphosis at T6. (*Right*) Prominent tuft of hair at L1 through L4 over the site of bony spicule at L2. Marked gibbus formation at T6.

constant central filling defect, about 2½ by 1 cm., by which the spinal canal seemed to be split into two halves. At the center of this filling defect, the above-mentioned bony ring shadow was seen.

1st Operation. On March 24, 1953 a laminectomy from L1 to L4 was performed, with disclosure of the defect shown in Fig. 4. This was removed. This spicule of bone was firmly attached to the under surface of the fused lamina of L2 and L3, which were markedly thickened and vascular. The attachment of the spicule of bone to the dorsal surface of L2 was thinner but still bony. The dura mater was separated from the spicule easily and when the bone was removed the cord was seen to move upward. The dura mater was not opened. No nerve roots could be seen coming off from the medial aspects of the two cords. The wound was closed without drainage.

Course. There was gradual loss of most of his spasticity in the following 10 days.

2nd Operation. On April 9, 1953 an exploratory laminectomy was performed at T5 to T7. There was moderate pressure on the cord at T5–T6 and T6–T7 by the laminae of T5 and T7. There were no pulsations seen in the cord. The cord did not seem to be stretched tightly over the gibbus at the time of the operation. However, because of the backward displacement of the T6 hemivertebra, the spinal canal was narrowed in an anteroposterior diameter and it

was felt that the lamina of T5 and T7 should be removed to free up the cord. There was no marked lateral shift of the cord to the left secondary to the moderately severe left scoliosis at this level. At the finish of the procedure the dura mater did not appear to be under tension and pulsations could be seen above and below the gibbus.

Course. The postoperative recovery was uneventful. On examination on April 15, 1953 there was flaccidity of the lower extremities with negative Babinski sign. There were no changes in the sensory level. On May 3, 1953 there was no improvement of muscle strength

FIG. 3. Lateral myelogram showing complete block of dye at T-6. Dotted line indicates position of hemivertebra.

FIG. 4. Myelogram showing division of spinal cord surrounding bony spicule at level of L2.

in either leg but improvement in touch sense to the upper legs was noted. Deep pain was felt down to the toes. There were occasional involuntary motions of both legs.

At a follow-up examination 1 year later, muscular control of the legs remained absent except for some flickers of motion in the quadratus femoris bilaterally. Deep pain and touch sensations had fully returned. Light touch sense was present over L1–L4 and S2–S5, but absent over L5–S1. Knee and ankle jerks were hyperactive and moderate clonus persisted. Spasticity was mild throughout both lower extremities. Sphincter control had remained normal.

DISCUSSION

This case has one point that may throw some light on the genesis of this disease. All authors agree that the embryological defect producing diastematomyelia occurs between the 21st and 27th day of gestation, at which time the formation of the

neural tube from the basal plate occurs. However, there is a difference of opinion as to where the abnormality begins. Herren and Edwards[6] and Benstead[2] felt that the primary defect is an abortive attempt at twinning by the totipotential neural tube in the development of the cord and that the bony malformation is induced by the abnormal configuration of the cord. To support this theory they point to the fact that in some cases of diastematomyelia all the surrounding mesodermal structures are normal, except for the dura mater and arachnoid, and to the histological appearance of the divided cords. Of the cases reported by Herren and Edwards,[6] 25 per cent show no record of associated bony defects. However, a survey of the literature since their publication shows that in all subsequent cases there were associated bony defects.[2–4,7,8,10,11]

On the other hand, the work of Spemann, as brought out by Campbell,[3] seems to show that: "Mesenchyme derived from the mesoderm of the supporting somites, in addition to supporting and protecting the neural tube, has the prime function of inducing it." Their work shows that abnormal mesenchymal tissue surrounding the neural plate causes marked changes in the development of the neural tube. Lack of normal surrounding mesenchymal tissue may cause the neural tube to take the form of a widened basilar plate with partial or complete spinal rachischisis of the type seen with meningocele or myelomeningocele. Diastematomyelia is an example of extreme rachischisis of ectodermal elements. In his views he is supported by Lichtenstein.[8]

In this case, two mesenchymal abnormalities were found, widely separated from each other by relatively normal vertebra, and with an apparently normal spinal cord. At laminectomy of T5-T7 the spinal cord appeared entirely normal except for the mechanical pressure of the posteriorly displaced T6 hemivertebra. This suggests an abnormality of the surrounding mesenchyme which, in the lower area, was of such a nature as to cause the neural tube to close improperly rather than suggesting that the primary defect was in the neural elements. It may be that the mesenchymal structures dominate from a genetic point of view, except under the more powerful transient stimulus of the host through factors such as elevated temperatures caused by infections of the mother, as is suggested by the work of Ancel.[1] Thus, it might be possible for hyperthermia of the mother to cause a neural defect without bony abnormality. Only more detailed questioning of the patient's parents can shed light on this factor in the etiology of this disease. The patient's mother in the present case had no recollection of any of the details of this portion of her pregnancy. Further speculation as to the etiology of this condition is unjustifiable.

SYMPTOMS

In the writer's opinion, the symptoms in this case conform more with those associated with kyphoscoliosis than with those commonly found associated with diastematomyelia. In none of the cases of diastematomyelia reviewed by Herren and Edwards[6] or reported by Matson, *et al.*[11] was paraplegia mentioned as an important factor. The onset of the symptoms of diastematomyelia usually occurred in childhood and progressed over a longer period of time before becoming marked. In kyphoscoliosis, the average age of onset was found to occur at puberty[5,9] and the symptoms were found to appear simultaneously and equally in both lower extremities. The neurological defects in diastematomyelia are usually more marked on one side, while those of kyphoscoliosis are almost always bilateral. Vesicular atony

with incontinence is not a prominent factor in kyphoscoliosis, as it is in diastematomyelia.

It is of interest that those who have worked on the problem of kyphoscoliosis have found it difficult to explain why certain scoliotics have paraplegia and others do not. According to Steindler, commenting on the paper of McKenzie and Dewar,[9] only 0.3 per cent of all cases of severe scoliotics or kyphoscoliotics in a large series from Iowa State University Hospital reveal symptoms of paraplegia. It appears to be much more common in cases of congenital scoliotics and McKenzie[9] reported that in one case of apparently idiopathic scoliosis, paraplegia was caused by the pressure of a congenital extradural band. The etiological factor of the paraplegia in these cases appears to be the tightness of the dura mater over the bony prominence rather than the amount of curvature of the spine or the rapidity of its formation. It was further postulated by McKenzie that there may be some abnormal fixation of the cord to account for the symptoms in such a small percentage of cases. This case revealed an obvious fixation of the cord and dura mater. When the fixation was released the neurological symptoms began to improve. This would tend to substantiate the above hypothesis as to the cause of kyphoscoliotic paraplegias.

It may be that in the cases of kyphoscoliosis with paraplegia there is some other related spinal abnormality that results in fixation of the cord in the course of its progression up the spinal canal, which causes symptoms to appear at the age of puberty because of the rapidity of growth of the spine at this time. This may be some congenital abnormality, as in the present case, or, in those cases of "idiopathic scoliosis," it may be that the same factor that causes the scoliosis is also responsible for the fixation of the dura mater of the cord. It would be of interest to study this problem more thoroughly by examination of autopsy specimens in cases in which laminectomy and decompression of the cord have been done with verification of the fixation of the dura mater during life.

It is regrettable that this patient was seen so late in the course of his disease. In treatment of these two conditions, early operation is to be desired before permanent damage to the structures of the cord has occurred.

The treatment for diastematomyelia is excision of the bony abnormality to remove the pressure on the nerve roots and to permit the cord to move upward in the spinal canal. The work of Matson, *et al.*[11] has been the most extensive in this field. The operation is done in these cases primarily to prevent further nerve defect, as the recovery of damaged nerve roots is seldom complete.

The results of operations to decompress the cord in cases of kyphoscoliosis with neurological symptoms have been more successful, and following wide decompression of the cord by splitting the dura mater, remarkable improvement has occurred.[5] Unfortunately in this case the patient had been paraplegic for almost 5 months before he was seen and his prognosis was poor from the beginning. No further improvement can be expected although it may be considered fortunate that his sensations have recovered.

SUMMARY

1. An unusual case of kyphoscoliosis with diastematomyelia producing paraplegia is presented.

2. The etiology of the resulting paraplegia is discussed.

3. Comments are made concerning the etiology of diastematomyelia.

REFERENCES

1. Ancel, P. Recherche expérimentale sur le spina bifida. *Arch. Anat. micr.*, 1946–1947, *36:* 45–68.
2. Benstead, J. G. A case of diastematomyelia. *J. Path. Bact.*, 1953, *66:* 553–557.
3. Campbell, J. B. Congenital anomalies of the neural axis. Surgical management based on embryologic considerations. *Amer. J. Surg.*, 1948, n.s. *75:* 231–256.
4. Cowie, T. N. Diastematomyelia with vertebral column defects. Observations on its radiological diagnosis. *Brit. J. Radiol.*, 1951, *24:* 156–160.
5. Gulledge, W. H., and Brav, E. A. Non-tuberculous thoracic kyphosis with paraplegia. A case report. *J. Bone Jt. Surg.*, 1950, *32-A:* 900–903.
6. Herren, R. Y., and Edwards, J. E. Diplomyelia (duplication of the spinal cord). *Arch. Path.*, 1940, *30:* 1203–1214.
7. Kapsenberg, J. G., and Van Lookeren Campagne, J. A. A case of spina bifida combined with diastematomyely, the anomaly of Chiari and hydrocephaly. *Acta anat.*, 1949, *7:* 366–388.
8. Lichenstein, B. W. "Spinal dysraphism." Spina bifida and myelodysplasia. *Arch. Neurol. Psychiat., Chicago*, 1940, *44:* 792–809.
9. McKenzie, K. G., and Dewar, F. P. Scoliosis with paraplegia. *J. Bone Jt. Surg.*, 1949, *31-B:* 162–174.
10. Marr, G. E., and Uihlein, A. Diplomyelia and compression of the spinal cord and not of the cauda equina by a congenital anomaly of the third lumbar vertebra. *Surg. Clin. N. Amer.*, Aug. 1944, *24:* 963–968.
11. Matson, D. D., Woods, R. P., Campbell, J. B., and Ingraham, F. D. Diastematomyelia (congenital clefts of the spinal cord). Diagnosis and surgical treatment. *Pediatrics*, 1950, *6:* 98–112.
12. Neuhauser, E. B. D., Wittenborg, M. H., and Dehlinger, K. Diastematomyelia. Transfixation of the cord or cauda equina with congenital anomalies of the spine. *Radiology*, 1950, *54:* 659–664.
13. Walker, A. E. Dilatation of the vertebral canal associated with congenital anomalies of the spinal cord. *Amer. J. Roentgenol.*, 1944, *52:* 571–582.

INTRAVENTRICULAR TORULA GRANULOMA

LOUIS O. J. MANGANIELLO, M.D., AND POMEROY NICHOLS, JR., M.D.
Department of Neurosurgery, Medical College of Georgia, Augusta, Georgia

(Received for publication January 14, 1955)

Torula granuloma of the brain seems to be an infrequent occurrence. Carton and Mount[2] reported 8 cases. Liu[3] in reviewing the literature added 5 more, and reported 1 of his own. Balakrishna and Lilauwala[1] reported 1 more, thus making a total of 15 cases in the literature so far.

However, in none of these 15 cases was the granuloma found within the ventricular cavities. The involvement of the central nervous system by Torula histolytica (Cryptococcus neoformans) may be classified as (1) the meningitic type, (2) the meningoencephalitic and (3) the embolic type. The last is responsible for the majority of granulomas found. There is another type, apparently not mentioned before in the literature, which involves the choroid plexus and produces granulomas. This can be called a choroid plexitis. The following case illustrates this.

CASE REPORT

A 61-year-old white male was first seen in the office on Jan. 16, 1954 having been referred by Dr. Wallace McNair of Aiken, S. C. His chief complaint was headache, which had become progressively worse, of 2 weeks' duration. He had had one black-out spell and two episodes of blurring of vision. He had noticed general progressive weakness and malaise for several months.

Past history was not contributory except for the fact that he had had a transurethral resection for prostatic difficulty 3 years before. Family history was not contributory. He was a carpenter by trade.

He was a listless, apathetic white male who complained bitterly of headache. He had a minimal left facial weakness of central type. There was a questionable Babinski sign on the left and some weakness of the left arm. Fundi were normal except for some arteriosclerotic changes.

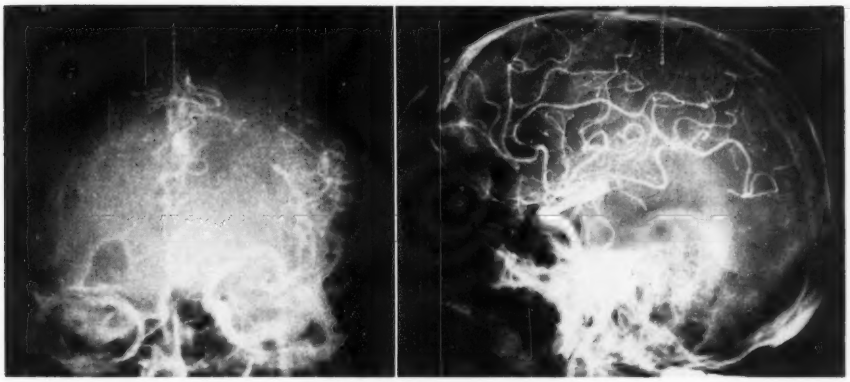
He was advised to enter the hospital for further study and was admitted on Jan. 17, 1954.

Examination and Course. Complete blood count was within normal limits. Urine was normal. Serological tests for syphilis was negative. Roentgenograms of the skull revealed multiple defects in the parietal and occipital bones. Roentgenograms of the chest showed considerable pulmonary congestion bilaterally with evidence of infiltration of the right base. Lumbar puncture done shortly after admission revealed a CSF pressure of 140 mm. of water. The fluid contained 14 white cells, 100 per cent of which were polymorphonuclear. Pandy was slightly positive; total protein was 115.

In view of the suspicious lesions in his skull and the possibility of metastatic malignancy, a medical consultation was obtained. In the meantime a right cerebral arteriogram was done which showed no abnormalities (Figs. 1 and 2).

Nonprotein nitrogen was 34, total protein 6.9, albumin 5.04, globulin 1.86, calcium 9.9, phosphorus 4.1, acid and alkaline phosphatase 2.2 and 2.9 respectively. Bence-Jones protein test was negative. Sternal bone marrow was normal.

At lumbar puncture on Jan. 21, 1954 pressure was 160 mm. of water. Cell count was 147 with 33 per cent polymorphonuclear cells and 67 per cent lymphocytes. Pandy was positive. This fluid was submitted for routine culture and for examination for tubercle bacilli and fungus.



FIGS. 1 and 2. Right carotid arteriograms, anteroposterior and lateral views.

Another lumbar puncture was done on Jan. 26, 1954. Pressure was 120 mm. of water. Cell count was 104, with 27 per cent polymorphonuclear cells and 73 per cent lymphocytes. Total protein was 75; sugar was 52.

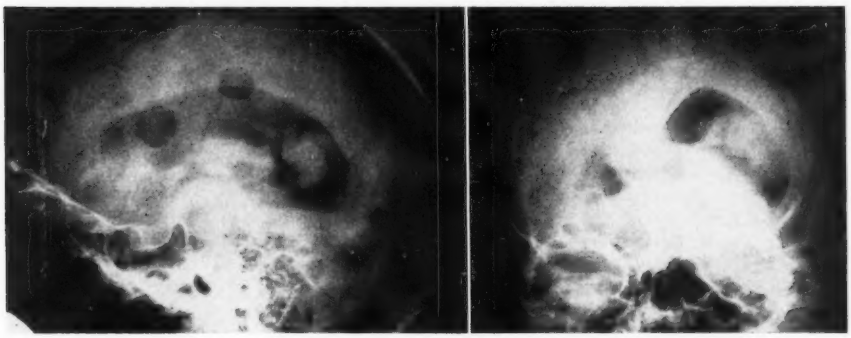
Gastro-intestinal series showed no abnormalities. Febrile agglutination tests, including heterophile, were negative. Temperature during this time ranged from 99° to 101°.

At lumbar puncture on Feb. 1, 1954 pressure was 180 mm. of water. Cell count was 125, with 12 per cent polymorphonuclear cells and 88 per cent lymphocytes. Smears of spinal fluid and cultures were repeatedly negative. Spinal fluid serology was negative.

1st Operation. On Feb. 4, 1954 exploratory trephinations were done to rule out a subdural hematoma and also to see if one of the skull lesions could be biopsied. There was no evidence of hematoma and nothing was seen grossly at the areas of defects in the skull that were indicated by the roentgenograms.

Course. Cultures for fungus and tubercle bacilli up to this date were reported as negative. That night the patient's condition was much worse; he became stuporous, and a left-sided paralysis developed. An emergency ventriculogram was done (Figs. 3 and 4). This showed an intraventricular mass in the posterior horn on the right side.

2nd Operation. A right parieto-occipital cranioplastic flap was turned. The dura mater was opened; it appeared slightly milky. A tunnel was made in the posterior part of the parietal



FIGS. 3 and 4. Ventriculograms showing mass in posterior horn of lateral ventricle.

lobe, exposing the posterior part of the right lateral ventricle. A gelatinous mass, measuring 4×5×6 cm., was found, which was attached to the choroid plexus. This was removed.

Course. The next day the spinal fluid cultures which had been started at the time of his first lumbar puncture revealed a growth which was identified as Torula histolytica. Pathological report on the tumor removed confirmed this diagnosis (Figs. 5 and 6). Following craniotomy he did very poorly; his temperature rose to 103° and death occurred on Feb. 14, 1954.

Autopsy. The findings, except for the brain, were noncontributory. The brain weighed 1675 gm. The gyri were flattened and sulci were narrowed. The cerebral cortex and overlying pia-arachnoid had a granular opaque appearance, more pronounced in the sulci. There were

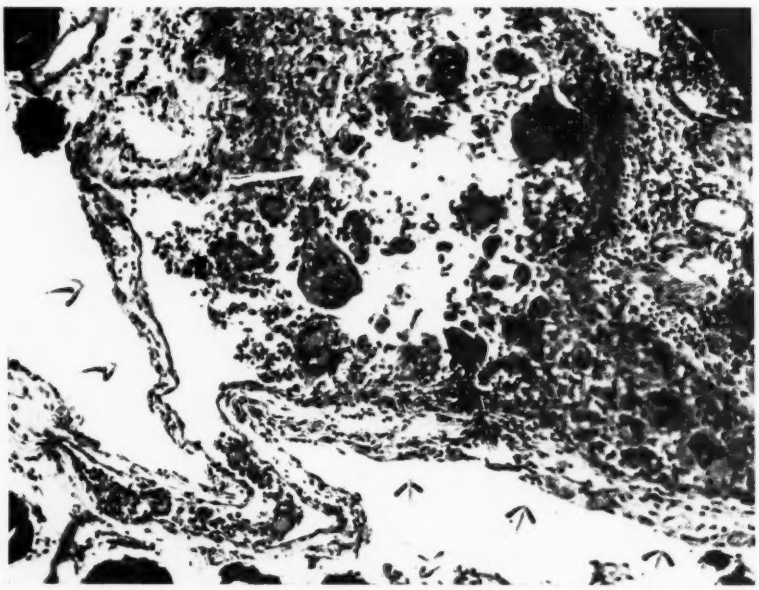


FIG. 5. Photomicrograph of choroid plexus granuloma (arrows) showing infiltration of round and giant cells and a moderate number of organisms.

20–30 cc. of serosanguineous fluid subtentorially. There was no evidence of gross encephalomalacia. There was pronounced cerebral edema, especially on the right side, with adherent, thickened, opaque, yellow-white pia-arachnoid.

Multiple coronal sections through the cerebral hemispheres revealed a dilated left ventricle with the right ventricle markedly encroached upon by surrounding edematous brain, especially the anterior portion of the caudate nucleus. The choroid plexus in the posterior horn of the left ventricle was not too well preserved and appeared slightly cystic. Little remained of the choroid plexus in the posterior horn of the right ventricle, except for several large vessels. Pons, cerebellum and medulla were not unusual.

Microscopic examination of the brain revealed the remains of Torula granuloma of the right choroid plexus, and Torula granuloma of the left choroid plexus with meningo-encephalitis. Slight hemorrhage was noted about the site of operation; no microscopic evidence of choroid plexus in the right posterior ventricle was found. The choroid plexus in the left posterior ventricle was infiltrated by round cells and giant cells, with a moderate number of organisms. Generalized meningeal reaction was present with a small to moderate number of

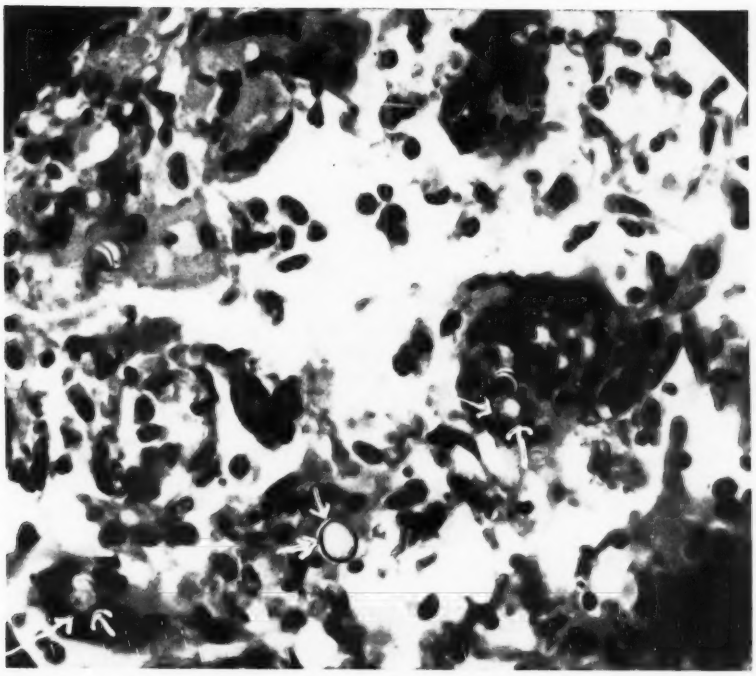


FIG. 6. High-power magnification of part of section shown in Fig. 5. Arrows point to organisms.

FIG. 7. Photomicrograph showing reaction in the meninges.

organisms. In sections of the pons there was perivascular round-cell infiltration with organisms. Cerebral edema was most pronounced throughout the right hemisphere. A chronic inflammatory cell infiltration with some organisms was noted along the stalk of pituitary.

Pathological Diagnosis. Torulosis: (i) granuloma, choroid plexus, right; (ii) granuloma, choroid plexus, left; (iii) meningo-encephalitis (Fig. 7).

DISCUSSION

The diagnosis of Torula was suspected early after the first lumbar puncture, but the cultures were repeatedly reported as negative. It took 18 days before the spinal fluid culture showed the organism. This stresses the importance of maintaining cultures at least 20 to 30 days when fungous infection of the central nervous system is suspected. The findings at ventriculography were compatible with the diagnosis of a ventricular tumor. This case is unusual in that the granuloma was located intraventricularly and involved the choroid plexus with very little meningeal involvement.

We have had experience in studying 8 cases of Torula and interest has arisen concerning the type of occupation these people were engaged in to see if there was a possible correlation between occupation and disease. In 5 of our 8 cases the patients had occupations that were connected with paper, pulp, or wood industry. Whether or not the organism is more prevalent in this type of occupation is purely speculation but it raises a question.

REFERENCES

1. Balakrishna Rao, B. N., and Lilaiwala, N. F. Cryptococcosis of the central nervous system with report of a case. *Indian J. Surg.*, 1952, *14:* 10–19.
2. Carton, C. A., and Mount, L. A. Neurosurgical aspects of cryptococcosis. *J. Neurosurg.*, 1951, *8:* 143–156.
3. Liu, C. T. Intracerebral cryptococcic granuloma. Case report. *J. Neurosurg.*, 1953, *10:* 686–689.

MALIGNANT ROUND-CELL NEOPLASM OF CEREBELLUM

SIMULATING AN ANGLE TUMOR WITH PETROUS RIDGE EROSION*

JOHN M. MEREDITH, M.D.

Department of Neurological Surgery, Medical College of Virginia Hospital, Richmond, Virginia

(Received for publication February 1, 1955)

The following case is unusual in that a malignant undifferentiated round-cell tumor of the cerebellum in a man aged 33 years produced a typical angle tumor syndrome with unilateral 5th, 7th, and 8th cranial nerve involvement and ataxia on the same side. It was thought pre-operatively that he probably had an acoustic neurinoma, particularly as roentgenograms (Towne position) of the skull showed erosion of the petrous ridge on the side of the cranial nerve involvement. However, at operation, he proved to have a medulloblastoma or other malignant undifferentiated round-cell tumor of the cerebellum originating on the side of the cranial nerves affected. The tumor had scarcely, if at all, invaded the angle and its nerves grossly, but seemed to cause the symptoms that it did by *intrinsic* cerebellar and brain-stem involvement, more than by direct extension into the lateral angle.

CASE REPORT

R. T., a 33-year-old white man, was admitted to the Medical College of Virginia Hospital on July 31, 1953, with a complaint that he had noticed deafness beginning in his left ear 3 years previously. This had gradually became more marked and 6 months before admission headache had developed and unsteadiness with falling particularly to the left side was noticed. For the last month or more, he had observed weakness of facial muscles and marked sensory diminution in the left side of his face, and loss of taste in the left side of his tongue. These complaints had all been progressive. In recent weeks he had been unable to walk without fixing his eyes directly on the path in front of him or on his feet. There had been several episodes of projectile vomiting during the 3 months before admission. He had fallen on several occasions and had noticed occasional amblyopia which was of only transitory duration.

Examination. Nystagmus was present in all directions. There was a 6th nerve weakness of the left eye, shown by inward squint of that eye. Hearing in the left ear was markedly impaired and there was definite sensory loss in the left side of his face, with diminution of the corneal reflex. There was no choking of the optic discs. The left side of the face showed muscular weakness of peripheral type. There was a definite tendency to fall to the left side when walking or standing. There was marked adiadokokinesis of the left hand and obvious ataxia in the left heel-to-shin test.

The clinical diagnosis was probable acoustic neurinoma in the left cerebellopontine angle with nearly total destruction of the function of the left 8th nerve. The otologist was unable to instigate any vertigo with an unlimited amount of ice water in the left ear; on the right side, 20 cc. of ice water produced vertigo and nystagmus. Roentgenograms of the skull on Aug. 1, 1953, including a Towne position film, showed *erosion* of the left petrous ridge, suggesting an acoustic neurinoma.

Operation, Aug. 3, 1953. Under endotracheal anesthesia, with the patient in the sitting

* Read at the sixteenth annual meeting of the American Academy of Neurological Surgery, October 21, 1954, at Colorado Springs, Colorado.

position, a hemicerebellar approach was made. The cerebellum was moderately tense even though a cannula had been introduced into the posterior horn of the left lateral ventricle. A moderate amount of fluid was evacuated from the cisterna magna when the dura mater was first opened. A brain retractor was placed laterally under the left cerebellar hemisphere and this structure was then lifted upward and medialward to expose the jugular foramen and the 9th, 10th and 11th nerves, which appeared normal. The 8th nerve was then seen clearly and there was no tumor present in that region. Because the cerebellum was rather full, it was decided to amputate the lateral third of the left hemisphere and in the process of carrying this out with a cautery and suction, a cavity (3×4 cm.) was entered into in the left cerebellar hemisphere from which exuded clear, yellow fluid, at least an ounce in volume. No tumor nodule such as an 8th nerve neoplasm could be palpated. After the cystic cavity had been evacuated, the cerebellum tended to fall away from the lateral sinus above; two large veins were coagulated immediately beneath the tentorium. The cerebellum was then retracted upward and medially and there was exposed a fleshy, somewhat fibrous but vascular tumor, about 3½×4 cm. in size, bluish-purple in color, which apparently arose *in the cerebellar hemisphere itself* and appeared grossly to be a glioma or other malignant invasive tumor. It definitely seemed to be contiguous with the subcortical cerebellar tissues rather than arising extrinsically (so far as the cerebellum was concerned) in the cerebellopontine angle. Several large portions of the tumor were removed for histopathological study and additional tumor was aspirated away from the site of the neoplasm. The dura mater was left open and closure was made in the usual manner without drainage.

Microscopic Examination. The tumor was a very cellular growth composed of small, dark-staining cells. It was quite vascular and hemorrhagic in one area. The diagnosis was malignant undifferentiated round-cell tumor: ?medulloblastoma or sarcoma (Fig. 1).

The original microscopic hematoxylin and eosin preparation of this tumor was kindly reviewed by Dr. J. W. Kernohan[6] of the Mayo Clinic, who considered the tumor to be probably an atypical medulloblastoma. He stated, "It is my opinion that it is closer to a medulloblastoma than any other tumor in the nervous system with which I am familiar."

The *postoperative course* was stormy, possibly because of the fact that the bony and dural decompression had been carried out only over the *left* cerebellar hemisphere. Respiration was precarious for several days in spite of frequent ventricular taps. His temperature reached 103° and 104° on several occasions, but with the administration of roentgen therapy his condition markedly improved and he left the hospital 25 days after operation in good condition. Because of the precarious immediate postoperative state of the patient, only 500 r of x-ray therapy was delivered to the tumor itself, additional therapy being administered in another state 2 months later; a total of 1,200 r was given in October, 1953 and in January, 1954. Thus a *total* of only 1,700 r was given to the tumor in the first 5 postoperative months.*

We did not see or hear from him until, in response to our letter of inquiry, it was learned from his family that he had succumbed on Feb. 20, 1954, approximately 6½ months after operative verification of the highly malignant undifferentiated round-cell tumor in the left cerebellar hemisphere.

COMMENT

Freid and Davidoff[3] in 1951 described a pathological entity: *primary cerebellar sarcoma*, easily mistaken for medulloblastoma microscopically. The sarcoma may also "seed" into the spinal meninges and even metastasize, i.e., involve distant viscera outside the central nervous system, even the skeletal or lymphatic systems. They reported 4 such cases. However, their description of these sarcomatous tumors

* *Preferred dosage:* Using 4 circular skull and 2 long spinal portals and doses of 250 r (air) to 2 portals daily, totals of 1,000 r (air) to each portal in a series delivers approximately 2,000 r to the tumor bed. These series are repeated at 6-week and later at 3-month intervals over a 1-year period using the usual 1 mm. copper half-value layer. (Technique of X-ray Department, Medical College of Virginia, Richmond, Va.)

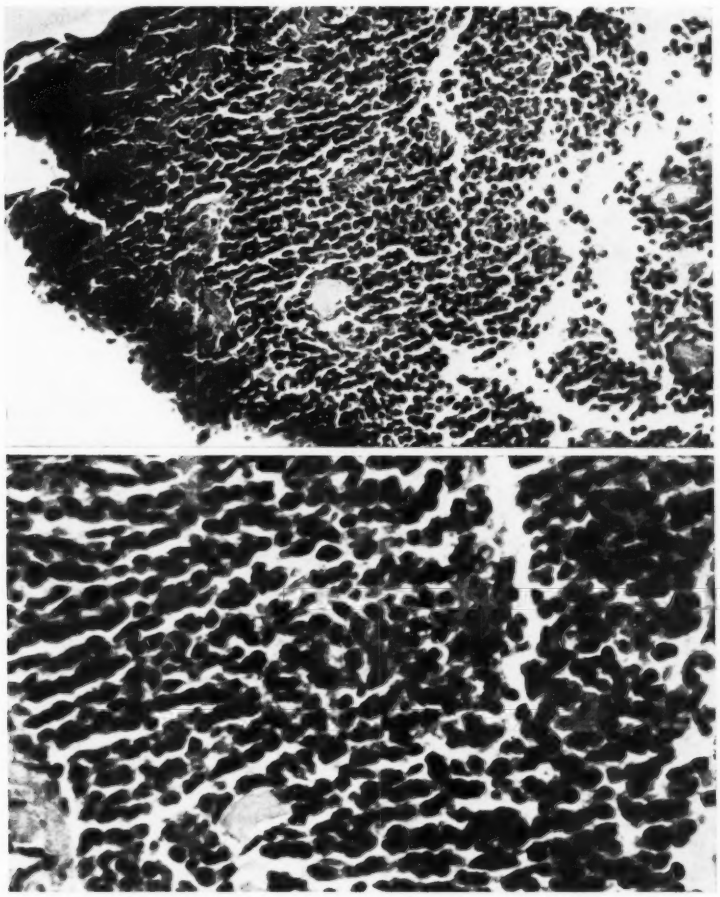


FIG. 1. (*Above*) There are diffuse sheets of compactly arranged cells with indistinct cytoplasmic borders, showing a superficial resemblance to lymphocytes. (Hematoxylin and eosin, ×100.) (*Below*) The nuclei are hyperchromatic, crowded and irregular. There are no rosettes. The appearance is that of a malignant undifferentiated round-cell tumor. (Hematoxylin and eosin. ×400.)

was preceded by at least two other reports. In 1929 Bailey[1] described clearly these malignant intracranial mesodermal tumors. He believed that they arose from the leptomeninges or their derivatives and he considered it advisable to call them sarcomas, for their structure differs considerably from that of rapidly growing intracranial tumors that are certainly of neuro-ectodermal origin. He reported 8 cases in detail and referred briefly to others in his experience. It should be noted, however, that in none of his 8 cases was the lesion a more or less localized cerebellar tumor either in one or both cerebellar hemispheres, as in the case herein reported. They were all either cases of diffuse meningeal involvement so that the meninges grossly

resembled tuberculous infection, or they were masses in the cerebral hemispheres or basal ganglia.

In 1939, Bailey, Buchanan and Bucy[2] described cerebellar tumors in children in whom the gross tumor as exposed at operation was indistinguishable from medulloblastoma and this was also true, to some extent, of the microscopic picture, according to these authorities. These latter statements are also valid for the tumor reported in this paper. They stated, "The course of events in these cases of malignant sarcomas is no different from the medulloblastomas." In describing one of their patients, a boy of 11 with a cerebellar tumor (Case 25, p. 107[2]), they stated, in reference to the microscopic appearance of the tumor: "We believe it to be a sarcomatosis but admit the difficulty of differentiating the two tumors, i.e., sarcoma and medulloblastoma." They also described a 17-month-old girl (Case 26) with a multilocular cystic tumor of the cerebellum (quite similar to that in the case reported herein) which was, microscopically, a sarcoma of the alveolar type. The short postoperative survival of the patient herein reported suggests that he may have had a cerebellar sarcoma, although the insufficient postoperative x-ray therapy was also a major factor in his early death.

The unusual features of the present case were several. First, a verified medulloblastoma or sarcoma cerebelli in an adult beyond the age of 30 is a rather unusual finding. Secondly, to our knowledge, there have been no previous cases reported in the literature in which a histologically verified malignant undifferentiated round-cell tumor of the cerebellum in a child or an adult has produced or has been associated with *erosion of the homolateral petrous ridge* demonstrated in roentgenograms of the skull, precisely as one sometimes sees in cases of acoustic neurinoma. Hodes, Pendergrass and Dennis[5] reported in 1951 on roentgenographic manifestations in 183 cases of cerebellopontine angle tumors of all types. In 16 of their cases the tumors were gliomas of the angle with cranial nerve involvement; in 1 of these 16 cases, an abnormal "petrous apex" was seen in the roentgenogram but they did not state whether it was a medulloblastoma or other round-cell malignant tumor as in our case, or one of the other types of glioma. Only 1 of their 183 cerebellopontine angle tumors was a medulloblastoma. In view of the unusual clinical features of the case reported in this paper, it is interesting to note that Hodes and his collaborators stated that gliomas in the angle seemed to occur more commonly in the younger age group, the average age of their 16 patients being 18 years, as compared with 40 years for patients with all other forms of angle tumor. Interestingly enough, Hodes and his colleagues found that none of the 16 gliomas in the angle were ependymomas, the microscopic diagnoses being astrocytoma, glioblastoma multiforme, spongioblastoma polare, and medulloblastoma. In contrast, Kernohan, Woltman and Adson[7] reported 10 cases of glioma in the angle in which 8 were ependymomas and the remaining 2 were fibrous astrocytomas, there being no instance of medulloblastoma or other malignant round-cell tumor (? sarcoma). Thirdly, the final unusual feature of the case herewith reported is that although there was obvious unilateral involvement, clinically, of the 5th, 7th, and 8th cranial nerves, grossly at operation this was not evident in the angle. The involvement must have been more medially or "nuclear" as the lateral angle was grossly free of tumor and the tumor-free nerves were clearly seen in the angle. We have recently had another patient (a 56-year-old white female) with a verified astrocytoma (grade 1) of the pons and cerebellum primarily, in whom there was also questionable erosion of the petrous ridge roentgenologically on

the side of the angle syndrome, which clinical picture was so suggestive of an 8th nerve tumor that operation was similarly performed in the erect or sitting position.

Concerning gliomas extending into the cerebellopontine angle, Kernohan, Woltman and Adson,[7] as mentioned above, reported in 1948 a series of 10 cases of such neoplasms, none of which, however, was a medulloblastoma or other malignant round-cell tumor. According to these writers, to make a pre-operative diagnosis of glioma or other malignant tumor in this location (cerebellopontine angle) would be hazardous; however, several factors would support such a diagnosis. In 7 of the 10 cases of glioma in the angle reported by them, the patients were children and the same number were of the female sex. Neurofibromas and meningiomas, as they pointed out, occur also in the cerebellopontine angle, usually in the later years of life. Two of the 10 patients with glioma in the angle that they reported complained of unilateral deafness, as did our patient, and this finding was also relatively frequent in cases of meningioma of the angle, according to these authors. A number of the illustrations in their paper show large ependymomas confined, for the most part, to the cerebellopontine angle. We have had in our service at the Medical College of Virginia in the last 18 years 2 other cases (a total of 4 at present writing) of gliomas involving the cerebellopontine angle and producing primarily an angle tumor syndrome, including deafness, but all of these except the present case herein reported were characterized by *gross invasion of nerves* in the angle by the glioma as seen at operation. One was in an adult colored woman, aged 23 years (operated upon by our then resident, Dr. M. McKeel, on Feb. 8, 1954), who had an ependymoma as verified at operation, performed in the sitting position since the preoperative clinical syndrome strongly resembled that of an acoustic tumor. The other was in a man of 30 operated upon (with recovery) in a 2-stage procedure 18 years ago by Dr. W. G. Crutchfield, then a member of our surgical staff. That patient had a medulloblastoma arising from a cerebellar hemisphere, which grossly invaded the angle and produced a syndrome very like that of the patient reported herein, namely, one highly suggestive of an acoustic neurinoma, with *early* deafness and unilateral ataxia and 5th nerve involvement. It was accordingly dealt with through a unilateral cerebellar approach, as one would attack an acoustic tumor today. An illustration of a gross brain specimen in Hicks and Warren's *Introduction to Neuropathology*[4] shows a postmortem specimen very similar to the lesion in our patient. However, that individual was a 20-year-old male with a medulloblastoma in the cerebellum who had progressive right cranial nerve symptoms for 6 months, starting with deafness. It was stated that the symptoms first were very suggestive of an acoustic tumor. In that gross specimen, showing the base of the brain, the tumor is grossly invading the angle also (precisely as in 3 of our 4 cases of glioma of the angle cited above) which was not true of the patient reported in this paper, rendering the present case rather unique in that respect.

SUMMARY

(1) Medulloblastoma or other malignant undifferentiated round-cell tumor of the cerebellum in patients over 30 years of age is a rather rare lesion.

(2) Roentgenographic evidence of *erosion of the petrous ridge* on the side of the malignant round-cell cerebellar tumor producing the cerebellopontine angle syndrome is entirely unique in our experience, thereby stressing the rarity of this case and suggesting how a cerebellar gliomatous or sarcomatous lesion can, pre-opera-

tively, easily be confused with acoustic tumor, particularly when associated with *early unilateral deafness.*

(3) The production of an "acoustic neurinoma syndrome" by a malignant round-cell tumor of the cerebellum *without gross invasion* of any of the nerves in the lateral angle as demonstrated at the time of operation is likewise unusual in our experience and unrecorded, to our knowledge, before the present case. The more usual pathological situation in cases of cerebellar glioma or sarcoma of the angle producing an angle tumor syndrome is for the 8th, 7th, 5th and even additional nerves in the angle to be *grossly involved* by the glioma or sarcoma, as occurred in the other 3 similar cases of this type from our clinic briefly referred to.

REFERENCES

1. Bailey, P. Intracranial sarcomatous tumors of leptomeningeal origin. *Arch. Surg., Chicago,* 1929, *18:* 1359–1402.
2. Bailey, P., Buchanan, D. N., and Bucy, P. C. Intracranial tumors of infancy and childhood. *Chicago: Univ. of Chicago Press,* 1939, xiii, 598 pp. (see chap. III).
3. Freid, J. R., and Davidoff, L. M. Roentgen therapy of primary neoplasms of the brain. *Radiology,* 1951, *57:* 25–36.
4. Hicks, S. P., and Warren, S. Introduction to neuropathology. *New York: McGraw-Hill Book Co., Inc.,* 1950, xiii, 494 pp. (see p. 350).
5. Hodes, P. J., Pendergrass, E. P., and Dennis, J. M. Cerebellopontine angle tumors: their roentgenologic manifestations. *Radiology,* 1951, *57:* 395–406.
6. Kernohan, J. W. Personal communication.
7. Kernohan, J. W., Woltman, H. W., and Adson, A. W. Gliomas of the cerebellopontine angle. *J. Neuropath. exp. Neurol.,* 1948, *7:* 349–367.

SUCCESSFUL REMOVAL OF INTRAVENTRICULAR ANEURYSM OF THE CHOROIDAL ARTERY

KENNETH J. STRULLY, M.D.*
New York, New York

(Received for publication February 4, 1955)

Tumors within the ventricular system of the brain have been thoroughly documented by numerous authors[6,7] and, in recent years, intracranial aneurysms have gained an increasingly prominent place in the medical literature.[1,8,9] An aneurysm of the distal portion of the choroidal artery is a rarity. When such a lesion reaches sufficient size to form an intraventricular mass, it is worthy of mention. The case report herein presented deals with just such a lesion.

REPORT OF CASE

D.S., a 27-year-old Puerto Rican female, was admitted to Beth David Hospital on Dec. 15, 1953. She complained of frontal headaches of 1 year's duration. They had been most frequent on arising in the morning, only occasionally coming on later in the day, and were usually relieved by aspirin. Two weeks prior to admission the headaches became constant, increasingly severe and were unrelieved by medication. She had nausea, vomiting and anorexia. Her vision became blurred and "cloudy." Occasionally she complained of diplopia.

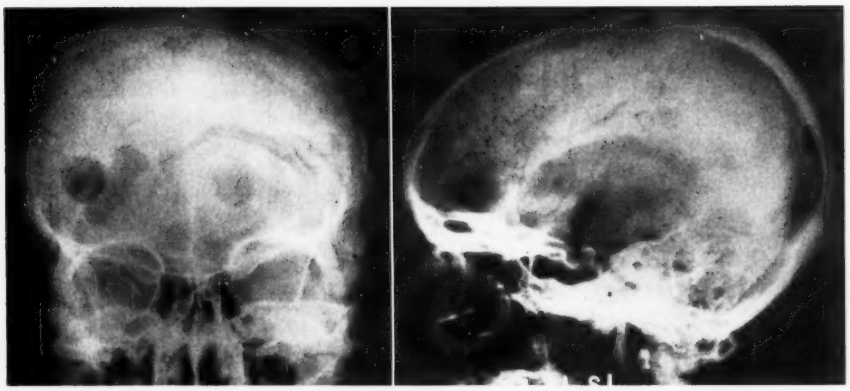
Examination. She was a well developed, well nourished, acutely ill, cooperative female. The right pupil was larger than the left and reacted sluggishly to light. A severe degree of papilledema was present bilaterally with hemorrhages and exudates. There were no localizing neurological signs.

The clinical impression was midline tumor in the third or fourth ventricle.

Ventriculography was performed on Dec. 19, 1953. Needles were passed into the lateral ventricles through occipital burr holes. Thirty cc. of clear colorless fluid escaped under greatly increased pressure. An equal amount of filtered air was instilled in small amounts alternately through each needle. The wounds were closed in layers with black silk sutures. Roentgenograms revealed a mass in the posterior portion of the left lateral ventricle with a shift of the ventricular system to the right (Figs. 1 and 2).

Operation, Dec. 19, 1953. Through a reverse Frazier type of flap in the left parieto-occipital area the underlying dura mater was exposed and found to be extremely tense. The patient was given 50 cc. of 50 per cent glucose and 0.5 gm. of caffeine sodium benzoate intravenously. A 1 mm. incision was made in the dura mater and brain. A cannula passed into the ventricle allowed air and fluid to escape, reducing the intracranial tension. The dura mater was then opened with the base of the flap toward the midline. The cannula was again inserted along the previous tract and at a depth of 5 cm. a firm rubbery mass was encountered. A circular area of the cortex—6 cm. in diameter—in the posterior parietal region was cauterized, the major vessels were clipped and cut, and a cone of cerebral tissue was removed to the ventricle. A dark red mass was seen at the depth of the opening. This mass was well encapsulated and firm, and was not adherent to the lining of the ventricle. With traction and the aid of a brain spoon it was possible to deliver the mass through the opening in the brain. During this maneuver a point of attachment could not be seen. However, with palpation along the inferior and medial edge of the tumor, a large blood vessel was felt. Before this could be clipped it was torn. The mass was quickly delivered and a large bleeding point was compressed through cottonoid

* 20 Fifth Avenue, New York, 11, N. Y.



FIGS. 1 and 2. Ventriculograms. (*Left*) Postero-anterior—horizontal. Left intraventricular mass partially outlined by air. Shift of ventricular system to the right. (*Right*) Right lateral—horizontal. Posterior two-thirds of left lateral ventricle not filled. Crescentic deformity at point of cut-off.

packing. It was then possible to clip and cauterize the bleeding vessel without serious loss of blood. This was a medium-sized artery in the choroid plexus of the ventricle. After the bleeding had been well controlled with cautery, clips and gelatin foam, the dura mater and flap were repaired in layers with interrupted black silk sutures. Split catheter drains were left in place beneath the bone flap and scalp.

Postoperative Course. During the first 48 hours the patient was irrational and exhibited a right hemiplegia. She began to improve thereafter. A right homonymous hemianopia and a moderate degree of aphasia were present. She could carry on simple conversations but anomia, alexia and acalculia were readily demonstrated. On Dec. 30, 1953 she was allowed out of bed. She walked with a hemiparetic gait on the right. She was transferred to Montefiore Hospital for rehabilitation.

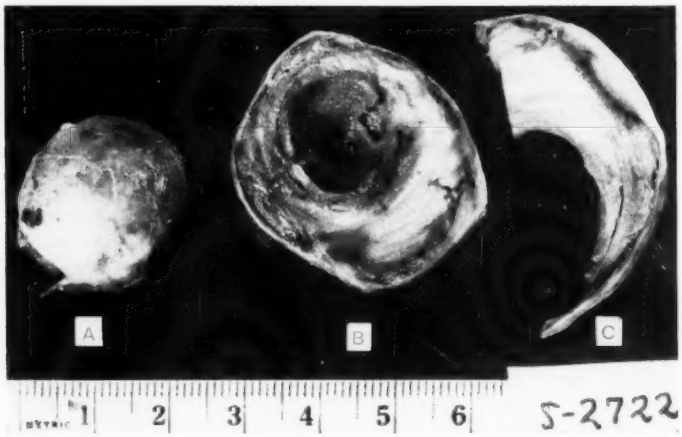


FIG. 3. Photographs of aneurysm. (A) The outer surface is smooth. (B) Lamellated tissue is seen in wall surrounding the central cavity. (C) A portion of the specimen viewed on edge.

Macroscopic Examination (Fig. 3). The specimen is a rubbery, yellow-pink smooth ovoid mass measuring 7×4×4 cm. On section a cavity, 1 cm. wide, filled with old blood extends along the greatest length of the mass. The smooth lining of the cavity is hemorrhagic. The wall of the mass is composed of lamellated yellow tissue.

Microscopic Examination (Fig. 4). A hematoxylin and eosin preparation reveals the wall of the mass to be composed of dense connective tissue infiltrated in patches by collections of lymphocytes. Attached to the wall is an organized thrombus which becomes progressively less organized toward the central portion. Most of the center is occupied by fresh thrombus with lines of Zahn. The wall contains well-defined media and adventitia. Elastic tissue stains

FIG. 4. Photomicrograph showing elastic tissue in the arterial wall. There is a lymphocytic infiltration, and the edge of the lamellated clot is shown. Elastic tissue stain, ×100.

demonstrate small amounts of internal elastic membrane. The picture is that of an aneurysm in which successive thrombotic episodes have occurred.

Diagnosis: Aneurysm of choroidal artery.

Comment. Angiography was not done in this case because there was no initial clue as to the location of the lesion and certainly none as to its nature. Even if angiographic studies have been carried out, it is doubtful that the aneurysm would have been demonstrated.

A careful survey of the past medical history of the patient failed to reveal any illness that might have possibly resembled an episode of intraventricular or subarachnoid bleeding.

DISCUSSION

Aneurysms of the choroidal artery have not been described before, as far as the writer knows. Lemmen and Schneider[9] reported an aneurysm of the posterior cere-

bral arteries causing occlusion of the posterior portion of the third ventricle in an 8-month-old child. Hamby[8] in his comprehensive study of aneurysms does not mention such an anomaly within the ventricular system nor is such reference made in case reports, surveys, anatomic and embryologic studies, or discussions of cerebral angiography.[1,4] From the standpoint of rarity alone such a lesion is of interest. Although this is an isolated case it may be of importance since it demonstrates another possible site for bleeding into the subarachnoid space, and the production of massive intracerebral or intraventricular hemorrhage. All too often the point of origin of intracranial bleeding cannot be demonstrated. The choroidal artery may be the offending vessel in such a catastrophe.

The present case demonstrates that aneurysms may occur at a point within the brain far removed from the major basal or cerebral vessels.

The arteries supplying the choroid plexus of the lateral ventricles are: (a) the anterior choroidal, which arises from the internal carotid and enters the plexus at the inferior horn; and (b) the posterior choroidal, a branch of the posterior cerebral which runs under the splenium. Beevor,[2] Carpenter and Noback[5] and others have demonstrated that the supply of the choroid plexus by the adult anterior cerebral artery is the least of its functions when compared to the distribution to the internal capsule and basal nuclei.

Padget[10] in discussing the development of the cranial arteries noted that the anterior choroidal and posterior choroidal arteries are identified in early embryonic life (7–12 mm. fetus). At this stage the largest branch of the primary cranial division of the internal carotid artery is the anterior choroidal. This supplies the diencephalon and enters the choroid fissure with the posterior choroidal artery which arises from a branch of the posterior communicating artery. In 12–14 mm. embryos the primary cranial portion of the internal carotid begins to assume the outline and branching seen with full development. The most proximal branch is the anterior choroidal artery, the middle cerebral is the second and next is the anterior cerebral. Upon reaching the 20–24 mm. embryos the circle of Willis is complete. At this stage Bremer[3] in 1943 first described a branch of the anterior cerebral artery entering the choroid plexus. This apparently does not persist since no such vessel is found in the human adult brain. The anterior and posterior choroidals anastomose in the region of the choroid plexus. Further development is in the pattern already established and results in the conformation found in the adult.

CONCLUSIONS

1. A case of successful removal of a massive aneurysm of the left choroidal artery is presented. The clinical picture was that of an intraventricular tumor and the nature of the lesion was not suspected until it had been removed.

2. A review of the literature establishes the rarity of such an anomaly.

3. The anatomy and embryology of the choroidal arteries is presented and the general clinical significance is discussed.

REFERENCES

1. Bassett, R. C. Intracranial aneurysms. 1. Some clinical observations concerning their development. *J. Neurosurg.*, 1949, *6:* 216–221.
2. Beevor, C. E. The cerebral arterial supply. *Brain*, 1908, *30:* 403–425.
3. Bremer, J. L. Congenital aneurysms of the cerebral arteries. An embryologic study. *Arch. Path.*, 1943, *35:* 819–831.

4. Campbell, E., and Burklund, C. W. Aneurysms of the middle cerebral artery. *Ann. Surg.*, 1953, *137:* 18–28.
5. Carpenter, M. B., Noback, C. R., and Moss, M. L. The anterior choroidal artery. Its origins, course, distribution, and variations. *Arch. Neurol. Psychiat., Chicago*, 1954, *71:* 714–722.
6. Cushing, H., and Eisenhardt, L. Meningiomas. Their classification, regional behaviour, life history, and surgical end results. *Springfield, Ill.: Charles C Thomas*, 1938, xiv, 785 pp.
7. Dandy, W. E. Benign encapsulated tumors in the lateral ventricles of the brain: diagnosis and treatment. *Ann. Surg.*, 1933, *98:* 841–845.
8. Hamby, W. B. Intracranial aneurysms. *Springfield, Ill.: Charles C Thomas*, 1952, xxi, 564 pp.
9. Lemmen, L. J., and Schneider, R. C. Aneurysm in the third ventricle. *Neurology*, 1953, *3:* 474–476.
10. Padget, D. H. The development of the cranial arteries in the human embryo. *Contr. Embryol. Carneg. Instn. 212*, 1948, *32:* 205–261.

JOURNAL OF NEUROSURGERY

The *Journal of Neurosurgery* is devoted to the publication of work relating primarily to neurosurgery, including studies in clinical neurophysiology, organic neurology, ophthalmology, radiology and pathology. Short articles on unusual cases and on technique, special instruments or equipment that might be useful to others in the field are also acceptable.

MANUSCRIPTS should be addressed to Dr. Louise Eisenhardt, 333 Cedar Street, New Haven 11, Conn., U.S.A. They should be typewritten in double space, with tabular matter and passages for small print on separate sheets. All materials should be mailed flat.

REFERENCES should be arranged alphabetically and cited by superior numerals in the text. The following order should be used:

Articles: Name of author, full title of article, name of periodical, year, volume, first and last page of article. Abbreviations of names of periodicals should conform to the style used in *A world list of scientific periodicals published in the years 1900–1933* (Oxford University Press, 1934).

Books: Name of author, full title of book, city, publisher, year, edition, full pagination (if book is in more than one volume, give the number of volumes).

ILLUSTRATIONS. Care should be taken not to use too many illustrations, since the Journal provides no figures free of charge. Color plates also are inserted at the expense of the contributor. If illustrations are larger than 8.5×11 inches, reduced glossy prints should be submitted instead.

SPECIAL TYPOGRAPHY. Tables and also text set up in small print in excess of 10 per cent of composition costs are charged to the author.

PROOF CORRECTIONS will be allowed without charge up to 5 per cent of the original cost of composition. The cost of changes in page proof, if made by the author, will be borne by him. *Page proof* will be submitted to authors only when special questions arise.

REPRINTS. Owing to existing paper shortage, no reprints may be supplied *gratis*. A schedule of charges for reprints is noted on the order forms accompanying the galley proof of each paper.

SUBSCRIPTIONS. The subscription rate for the volume of six bi-monthly issues is $11.00 in the United States and Pan-American Union; $11.50 in Canada; $12.00 in other countries. Single copies are $2.00 postpaid. Single copies of Volume VIII, Number 1, January 1951 issue: A Symposium on Intracranial Vascular Abnormalities: $3.00 postpaid, if available. Volume I, Number 1 is supplied only on orders for the complete volume. Payments may be made in advance to Charles C Thomas, Publisher, 301–327 East Lawrence Avenue, Springfield, Illinois, U.S.A.

CONTENTS

1. Angiography in the Management of Intra- and Supra-Sellar Tumours. R. A. Money, and G. K. Vanderfield 203

2. Peritoneal Shunts in the Treatment of Hydrocephalus and Increased Intracranial Pressure. A 4-Year Survey of 62 Patients. Ira J. Jackson, and S. R. Snodgrass 216

3. A Note on the Use of 25 Per Cent Iodopyracet (Diodrast) in Cerebral Angiography. D. L. Sutherland, William C. Kite, Jr., J. F. Roach, and Eldridge Campbell 223

4. Circumvention of Anoxia during Arrest of Cerebral Circulation for Intracranial Surgery. W. M. Lougheed, and D. S. Kahn 226

5. The Use of Hypothermia in Surgical Treatment of Cerebral Vascular Lesions. A Preliminary Report. W. M. Lougheed, W. H. Sweet, J. C. White, and W. R. Brewster 240

6. The Importance of the Deep Cerebral Veins in Cerebral Angiography with Special Emphasis on the Orientation of the Foramen of Monro through the Visualization of the "Venous Angle" of the Brain. Paul M. Lin, John F. Mokrohisky, Herbert M. Stauffer, and Michael Scott 256

7. The Diagnostic Significance of Restricted Ocular Motility in Children. Robert G. Murray 278

Case Reports:

Osteoclastoma of the Skull. B. Ramamurthi, G. S. Visvanathan, and K. M. Pillai 287

Cerebral Granuloma Caused by Schistosoma Japonicum. Takao Mitsuno 291

Diastematomyelia Associated with Dorsal Kyphosis Producing Paraplegia. William D. Shorey 300

Intraventricular Torula Granuloma. Louis O. J. Manganiello, and Pomeroy Nichols, Jr. 306

Malignant Round-Cell Neoplasm of Cerebellum Simulating an Angle Tumor with Petrous Ridge Erosion. John M. Meredith. 311

Successful Removal of Intraventricular Aneurysm of the Choroidal Artery. Kenneth J. Strully 317

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WISCONSIN